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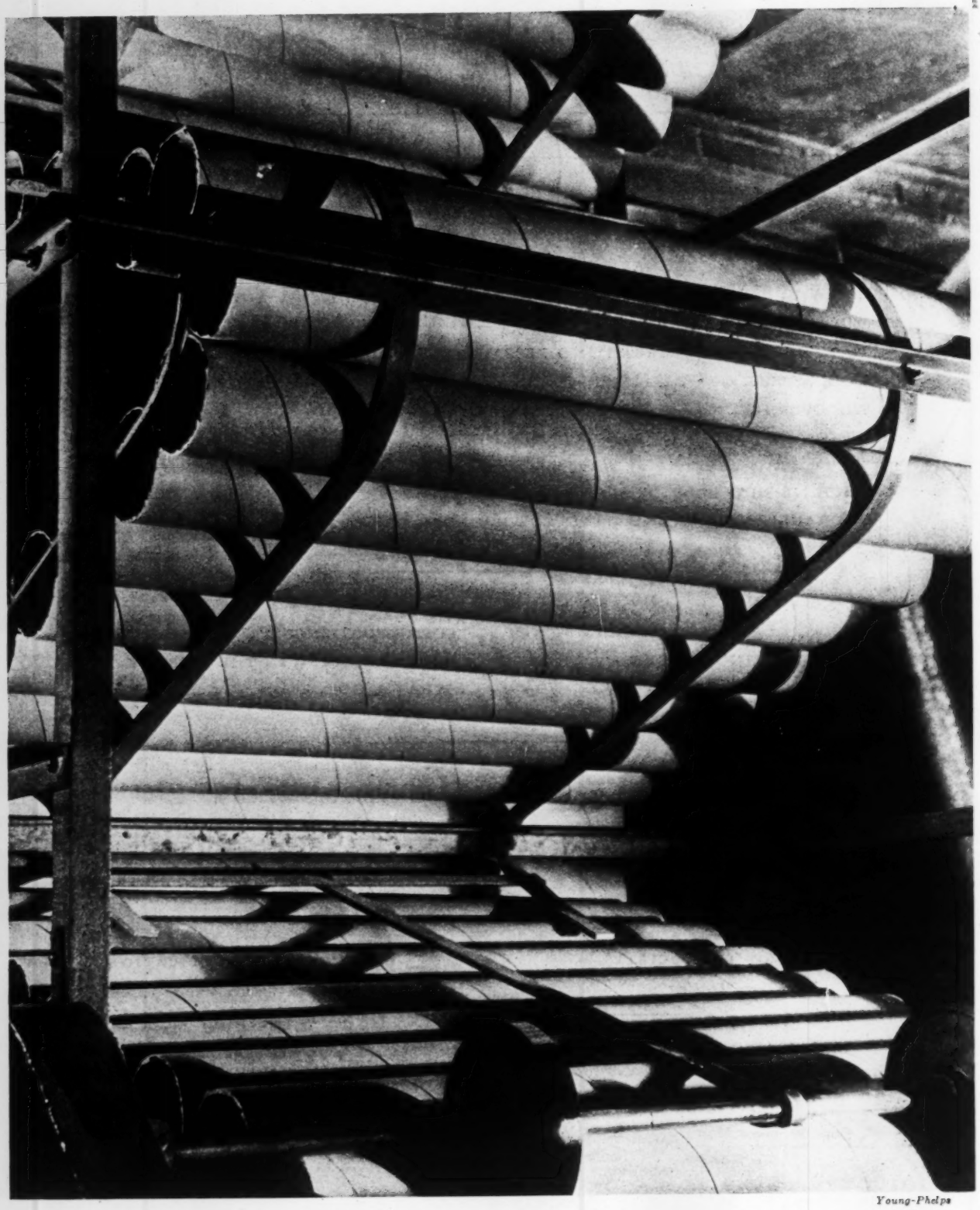

Young-Phelps

Regimentation in an Oatmeal Factory

INDUSTRIAL MANAGEMENT, 1934

A Report of Progress in Management[1] Prepared by the A.S.M.E. Management Division

THE year 1934, in striking contrast with the industrial recovery of the previous nine months, covered a period of reaction due in great part to new and impending reforms affecting certain phases of our economic, agricultural, and industrial order; the wide-spread drought; and the almost complete interruption in the promotion of new enterprises. Confidence in the future has been greatly lessened by a false theory developed in the minds of the general public, average business man, and investor that the ultimate had been accomplished along creative and inventive lines. As in the past, this theory will again be proved false, and in recent months organized effort[2] on the part of our scientific, educational, and industrial leaders has been made to dispel this age-old erroneous conclusion.

Unfortunately, the Administration at Washington labeled its program as revolutionary, whereas, if properly carried out, it must be evolutionary in character. The average business man's reaction was and still is one of apprehension. Many industrial changes, some of which are basically sound, were inaugurated on a broad scale and hastily placed into effect on a country-wide basis. Much unfavorable reaction could have been avoided by following the advice of some of our industrial leaders[3] who strongly advocated that these new ideas should be developed in a logical manner first on what might be termed a laboratory or limited-scale basis and then extended to industry as a whole after the plan had been worked out in practical form.

The conditions following the depression together with the publicity given to all the recovery measures has resulted in an aroused public interest in the legitimate confines of business wherein reform and recovery have been seriously confused. Social reformers, politicians, and numerous factions have attempted to capitalize this opportunity to force on business, and the whole country indirectly, their own particular theories and to gain special advantages without regard to the fine balance necessary to keep the wheels of industry and trade in motion if all are to maintain and better our American standard of living. The past acts of a comparatively few unscrupulous business men should not be sufficient to condemn the large majority who wish to conduct business in an entirely fair and honest manner.

The administration of business has taken on new functions and strengthened existing ones. Public relations have assumed a position of importance, and industry is taking a more active part in politics on a united front not so much as a matter of lobbying, but to see that it and its large army of employees have proper representation, and to prevent undue regulation by the Government. With the nation thinking in terms of individual security, business leaders are more and more viewing their position as one of trusteeship for the funds and good will the public has placed in their hands. Industry is exercising its own right to govern itself and in so far as possible to curb unethical practise. It is no longer content with profit from special privileges disregarding the social cost; it is using its personnel and resources to study economic conditions and derive a profit from foresight and efficiency, and at the same time it is contributing toward increasing the standard of living of the country as a whole. As a matter of fact, the United States is now emerging from a period of relatively unbounded resources to one having clearly defined limits, requiring more intensive and coordinated effort if progress is to be made.

Changes must and will come in both the technical and social fields. Progressive industrialists, managers, and engineers have recognized this fact, for example, in formulating and carrying out policies in regard to employees and the public, which in many cases have been to their disadvantage from a profit standpoint. Relatively these organizations will now benefit as the result of an extension of such policies to associated and allied industries.

In the midst of all this, men in executive positions have responded well to their added duties, and the public can rightly expect that the Government at Washington and management in industry will fully cooperate in placing their relationship on a more practical working basis.

PLANT LAYOUT, PROCESSES, AND EQUIPMENT

Plant rearrangements have been made in a number of industries by setting up unit organizations which, in effect, from a management standpoint, establish small business units within larger ones. In many cases this has simplified management problems, in particular, reduced costs involved in overhead organization units, and has resulted in a more rapid turnover of inventory in process and shorter periods of delivery. An outstanding example is that of a knitting mill which has rearranged its entire operations so that certain articles are completed on one floor of the factory. The new arrangement thus provides for continuous and rapid flow of work in process, and, as a result of the greater ease and improved facilities for supervision, the quality of the product has also improved.

While there is still considerable excess manufacturing capacity and equipment as the result of the present relatively low industrial activity, progressive companies have had the courage and foresight to replace part of their equipment by higher production and more efficient machines developed during the last three or four years. This is becoming increasingly important now that industry as a whole is faced with rising labor costs, and in addition, many changes in product design have made existing equipment obsolete from the standpoint of competing and still obtaining a fair margin of profit. Restrictions set up by the NRA in certain industries, which practically prohibit increases of productive capacity regardless of the relative efficiencies of the various plants, are having a very unsatisfactory reaction on the production of capital goods, especially in the machine-tool and special-machine fields. Employment in the

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[1] This report was prepared by the following committee: J. R. Shea, *Chairman;* J. A. Piacitelli, *Vice-Chairman;* W. H. Kushnick, *Secretary;* F. E. Raymond, G. W. Kelsey, W. Rautenstrauch.

[2] Dinner Conference in Hall of Progress, General Motors Building, Century of Progress Exposition, Chicago, May 25, 1934.

[3] Mr. Owen D. Young, Chairman, Board of Directors, General Electric Company, in a recent address before the University of Nebraska.

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machine-tool and other capital-goods industries has been at a very low ebb, in many cases even prior to the depression in the fall of 1929. Even with only a modest pick-up in activity, it is now very clear that such industries will have extreme difficulty in manning plants with a well-balanced and efficient personnel. In fact, in certain of these industries scarcity is developing in the skilled trades involved in tool building, machine building, and maintenance. This situation is not so startling when it is considered that during the last five years practically no apprentices have been trained and graduated into full-fledged artizans and that our present mechanized civilization requires an ever increasing number of such men in our forward march of progress. In contrast, during this period men formerly in these fields have adopted other occupations, have been pensioned, retired, or are deceased. Recently, the national Government has seen this condition as one to be corrected by an extension of our general educational facilities.[4]

INDUSTRIAL RELATIONS

Industrial relations have rapidly assumed nation-wide proportions under the operations of the National Industrial Recovery Act and they bid fair to continue so with the passage of the Wagner-Lewis Bill and the establishment of the National Labor Board. Apparently, for some time to come industry, whether it likes it or not, is due to follow a lead in matters of personnel policy from Federal agencies rather than from individual plant problems and the desires of its own leaders. For the time being, further development of the traditional activities of the personnel department await the settlement of what the status of labor will be under the "New Deal." Much depends upon the early discussions of the National Labor Board in interpreting many questions in dispute as to what course industry will pursue in the immediate future.

The first year of operation under the codes has been marked by increasing labor unrest. To cope with this situation the Government has been forced to intervene in a great many disputes. While the appearance of the Government as a factor in industrial relations has from a management point of view complicated an already highly charged situation, it is clear that intervention was essential from a recovery angle.

The code program has increased labor costs but without increasing real earnings per employed worker, and without substantially reducing unemployment. A few figures will indicate this.[5] For the period June, 1933, to April, 1934, average hourly earnings, a fair measure of labor costs, rose from 41.9 to 54.1 cents. Per capita weekly earnings, however, increased only from $17.99 to $19.96, a gain almost precisely offset by an increased cost of living. However, since September, 1933, there has been no net absorption of the unemployed.

Mounting unrest is in part attributable to this situation. But the wave of strikes in the spring and summer of 1934 has been highly augmented over the normal tendency to strike while emerging from a depression by labor's disillusionment over Section 7*a* of the NIRA. Unlike the hopeful strikes of 1933 the current ones are increasingly bitter. They are directed toward securing the recognition which labor expected from the Government's guarantee of the right to bargain collectively. The new National Labor Relations Board seems committed to a policy of enforcement. Yet it is difficult to imagine such a thorough-going revolution in employer sentiment necessary to secure peace under present conditions. Even given such a change in sentiment, employers simply could not suddenly meet labor's demands for increased wages and shorter hours without compensating factors such as increased business, improved methods of manufacturing, and improved ways of doing business. Current strikes have another interesting feature. They are in many instances being supported by the organized unemployed or by the general community. Under these conditions these strikes are assuming the proportions of social upheavals.

What has management done under these trying conditions? It has been forced to a broader and more thorough recognition of the importance of labor relations. The relatively few companies with a personnel policy have been actively revising or at least re-thinking their policies, while the many companies who have drifted along with no policy have been forced to adopt one. Much trouble has arisen from hasty changes. In some cases a "stand pat" policy has been adopted and the lid has been clamped on tighter, or an employee-representation plan has been hastily put in force. Both moves are productive of trouble. The National Labor Board was flooded with cases involving discrimination against union members and inadequate representation plans. Companies already having plans of recent or long standing have placed the entire plan in the hands of employees and have adopted definite policies in their relation to it to avoid even the appearance of interference, coercion, or intimidation. Progress has been made in federating plans of the same company in different localities, or of plans of different companies in the same industry, or in the same locality. Many concerns are for the first time dealing with labor organizations. Many more will have to, for unions are springing up and becoming powerful in hitherto unorganized industries and areas, rubber plants, copper mines, aluminum plants, steel mills, just to mention a few. The vexed question of minority representation complicates relations in some concerns.

Industry's responsibility regarding unemployment has been increasingly recognized. Current unemployment is a relief problem, but something can and no doubt will be done about unemployment in the future. While there has been active discussion of company reserves plans, only sixteen are in operation and only two new ones were started in 1934. Demand for legislation to provide unemployment benefits has continued active, but no states have followed Wisconsin's lead. Failure to do so may be attributed to lack of agreement among sponsors regarding the precise nature of desirable legislation, to uncertainty regarding possible Federal action (Wagner-Lewis Bill), and to continued opposition of organized business interests. The President's appointment of a commission to study social insurance suggests the probability of action at the next session of Congress. Opportunity should be open for progressive industrial leaders to take an active part in preparing such legislation.

In the pension field the outstanding event was the enactment by Congress of a compulsory pension plan for railroad employees. The political power wielded by organized labor in the present administration was well demonstrated, especially as the law comes at a time when the railroads are not ready to bear the financial burden, and the result may be an important factor in the retardation of economic recovery. It is too early to guess what the President's social-insurance commission will recommend on old-age pension, but it would not be surprising if some form of Federal aid for states passing pension laws would be recommended. Twenty-six states already have such laws. Individual companies meanwhile are reexamining their pension plans or considering more seriously their adoption. The trend seems to be toward contributory schemes put upon a sound actuarial basis. Experience with non-contributory,

[4] Executive Order: Rules and regulations.....as they may affect apprentice-training programs in industry, signed July 27, 1934, by the President.

[5] National Industrial Conference Board, "Review," June, 1934.

non-contractual plans has, as a whole, not been a happy one during the depression.

What other changes in labor relations in the nature of further social reform are just over the political horizon, it is difficult to say. Social security seems to be the main objective of governmental endeavor and how far this will go will be determined only in the long run by the economic cost to taxpayers, and eventually the cost to the consuming public.

Another aspect of the labor situation is the question of what the worker does with his leisure time. In many ways this problem is of growing concern to industry and the personnel manager. More leisure may mean contented employees, more spending, and high standards of living; but if not properly directed it could easily result in greater discontent and possibly social strife. If planned leisure and recreation can lead to a healthier and more alert industrial community, business and the nation stand to gain. A recent survey[6] by a well-known concern in the food industry shows that of 133 of its employees, 84 per cent of the men and 68 per cent of the women read more; 64 and 44 per cent, respectively, did more gardening; 59 and 24 per cent gave more time to sports; while 34 and 27 per cent devoted more time to general recreation.

HUMAN RELATIONS AND INDUSTRY

Progress made in human relations in industry during the past year is exceedingly difficult to outline without more perspective. In all probability we are entering a period of increasing change in the relationships of management and men. In the first place, the collective-bargaining clause of the Recovery Act has greatly affected labor relations. Second, there is evidence that management is increasingly realizing the importance of favorable employee attitudes upon the efficiency of industrial operations. It is being recognized that we must manage employees in such a way that we not only have the participation of their hands in industrial operations, but of their spirit and will as well.

A beginning of a scientific study of employee attitudes and the factors affecting them is to be observed in the reports of Elton Mayo[7] and R. S. Uhrbrock.[8] Such studies provide invaluable data to management which permit it to determine how various influences affect the employee. From an accumulation and analysis of a large quantity of such evidence it should be possible to formulate generalizations which will validly state their cause and effect relationships. Thus, for example, if it is known that certain conditions of human relations exist in a given plant, it should be possible to predict the morale of that plant as indicated by the attitudes and behavior of the employees.

DEVELOPMENT IN MARKETING

It is evident that Government activities, particularly those of the National Recovery Administration, have held first position as an influence on marketing during the past twelve months. Numerous problems have been created, a few solved.

While uncertainty and skepticism have prevented a general adoption of the fair trade practises advocated by those who have struggled with the formulation of codes under Government surveillance, some of the more vicious violations of public confidence have been corrected and effective steps have been taken in a few instances to restrain companies from advancing prices beyond the actual increase necessitated by higher labor costs. It would seem that some trade associations with Government support for their code stipulations have missed an opportunity for marked progress by failing to prosecute more promptly certain flagrant and publicized violations.

The code restriction against "loss leaders" has been effective with some of the larger department-store and chain organizations as well as many small retail units, and is resulting in a tendency to transform nationally advertised brands to be the backbone of profitable operation.

Restrictions against indiscriminate price cutting have met with difficulties in the face of intensely price-conscious buyers. Yet, it is evident that many manufacturers and distributors are placing less emphasis on price in their selling efforts and greater emphasis on quality, service, and satisfaction. This movement has been aided by an adverse reaction on the part of buyers to the recent influx of low-price, low-quality products. Purchasers have always become more critically selective when emerging from a period of economic stress.

Special attention has been directed to consumer education and to more effective sales promotion based on value in use. The problems of those who sell are becoming more like the problems of those who buy, which indicates and has registered the need for a more thorough knowledge of customer requirements. Capable marketing research, undertaken to obtain a more accurate picture of the needs, desires, and reactions of those who buy, is making rapid progress toward its acceptance as a necessary business tool. The operation of this technique is paying handsome dividends to those who have grasped its significance.

During the last three years, but more intensely, perhaps, during the past twelve months, there has been a wholesale turnover of executive personnel among firms who have survived the depression. Thus, the marketing map for those who "sell" industry has been materially changed. New contacts must be made. New people must be "sold." New prospects must be educated, even in firms that have been habitual customers. The need for close control of expenditures has, in many instances, been responsible for moving buying decisions "up-stairs," and it is likely that they will stay there for some time to come. This calls for a cultivation of new contacts and the revision of mailing lists in an effort to reach the men who actually buy.

One of the most important trends of the past few months has been a wave of resentment against misleading and dishonest advertising. This has been articulated by such organizations as the American Home Economics Association, trade associations, better-business bureaus, and consumer groups, outstanding among these being Consumers' Research. The strongest condemnation, however, has come from within the advertising fraternity itself. An outstanding advertising journal, *Printers' Ink*, states that "the iniquities of crooked advertisers are so universally known and are so openly and brazenly practised as to constitute a scandal." While this movement for honesty in advertising is not well organized and while little progress is apparent to date, a commendable improvement may be expected in the near future.

The effort to increase sales by bringing out new products or by improving the quality or finish of old ones is gaining momentum with a return of optimism. This is true of the capital-goods industry where better performance is being emphasized and in the consumer-goods industry where appearance is now generally recognized as a selling asset.

Product design, particularly from the standpoint of appearance of product or container, is receiving more intelligent attention than heretofore. This attention spreads from a consideration of the unit itself to a study of the ensemble effect of

[6] See *Factory Management and Maintenance*, April, 1934.

[7] "The Human Problems of an Industrial Civilization," by Elton Mayo, The Macmillan Company, 1933.

[8] "Measuring Attitudes of 4500 Factory Workers," by R. S. Uhrbrock, to appear shortly in the *Journal of Social Psychology*. "Human Relations in Changing Industry," by H. W. Hepner, Prentice-Hall, 1934.

merchandise with the associated products with which it must be displayed, and also a study of pleasing appearance when in use by the ultimate purchaser.

In contrast with these many changes, an officer of a well-known electrical manufacturing concern has had the temerity to challenge the American practise of frequent style changes and high obsolescence. This may initiate a change in industrial philosophy, or, on the other hand, it may be no more than "a squeak in the wilderness."

Realizing that social legislation advocated by the present Administration tends toward a redistribution of wealth rather than an increase in individual wealth, alert manufacturers and merchandisers are studying the direct and indirect buying influence of the low-income group which collectively and relatively may have more spending power than formerly.

WAGE INCENTIVES

An analysis of the numerous modifications of the President's original reemployment agreement approved for different industries shows that in 211 companies who changed the wage provisions of the agreement 57 per cent permitted less than minimum wages for apprentices or learners; 30 per cent, lower rates for women than men; and 37 per cent, lower rates in the South than in the North. Other regional differences were recognized in 8 per cent of the modified agreements, while 9 per cent replace the single minimum of the agreement by different minimum rates for different occupations. In allowing departures from the rule of uniformity the approved codes have in some particulars gone further. The first 123 codes were analyzed with respect to wage differentials, and with office workers, 27 per cent permit less than the minimum rates for office boys and girls while 28 per cent follow the lead of the agreement in fixing minimum rates according to the locality. For factory workers, 52 per cent provide lower rates for learners and apprentices, and 33 per cent extend similar rates to partially incapacitated persons.[9]

From March to July, 1933, before the adoption of the codes of fair competition, average weekly hours, total employment, and total payrolls increased, due largely to expanding production. In spite of increased production average hourly earnings declined although the per capita were somewhat larger due to longer hours per week. After July, during the operation of the codes and the President's reemployment agreement, average hours per week declined sharply due in part to declining production, but in those industries where production did not decline the effect of the codes was apparent in a general reduction of average hours per week. In both manufacturing and non-manufacturing industries reporting to the United States Bureau of Labor Statistics there was a general upturn after July, 1933, in average hourly earnings, total employment, total payrolls, and per capita earnings. At the same time there were sharp declines in average hours per week and in total production.

In 78 manufacturing and 14 non-manufacturing industries the average hours per week were 15 per cent lower in March, 1934, than July, 1933, and the average hourly earnings 26 per cent higher. The Bureau's index of employment based on a total of 90 industries was 13 per cent higher and its index of payrolls was 27 per cent higher, although the Federal Reserve Board's index of production was 12 per cent lower.[10]

Since July, 1933, these wage adjustments have been taking place gradually. Of the thousands of manufacturing and non-manufacturing establishments reporting to the United States Bureau of Labor Statistics each month many have reported substantial increases in wage rates while a few show decreases, the latter occurring generally in small establishments. Reports covering a period from May 15 to June 15, 1934, were received from 23,347 manufacturing establishments employing 3,750,605 workers. Of these, 359 establishments in 58 industries reported wage-rate increases averaging 9.8 per cent affecting 53,366 employees. Six establishments reported decreases which averaged 12.8 per cent and affected 193 workers.[11]

Many factories which abandoned their incentive plans during the depression face the question of restoring them as production begins to increase again. There is no question of the ultimate advisability of paying on the incentive basis, but employers eager to get back to the benefits of incentive plans are now giving careful consideration to the labor tension that traditionally accompanies a revival after a depression. Some thought is being given to the attitude of the few workers who feel that speeding up the pace through incentives, especially in times of low production, will throw more people out of work. With expanding production, industry will face the problem of training large numbers of people and it is expected that tensions will arise when skilled and unskilled people work at the same job with different earnings. However, properly set standards of performance and adequate incentive provisions for learners will do much to relieve such situations.

An incentive plan for supervisors was applied in one plant and resulted in reducing the controllable operating expense 10 per cent. In this organization the improvement of manufacturing methods is left to the engineering and time-study departments. The plan is based on the supervisor's ability to keep expenses under his control to a minimum, maintain quality of output, meet production schedules, and maintain satisfactory relationship between the company and employees of his department.[12]

Interesting results were secured in some recent investigations on various wage-incentive plans in repetitive work by the Industrial Health Research Board (Great Britain).[13] Ten girls of different temperamental types who performed five operations each in a commercial factory were made subjects of a test. Actual tests were made which directly compared day work or fixed wage per hour with a flat piece rate and in turn with a group bonus plan. The latter produced the best results.

JOB STANDARDIZATION AND ANALYSIS

Steady progress is being made in the application of motion study in industry. Results of savings in time and effort have been reported in clerical as well as manual work. One company reports the improvement of bench assembly work. Another gives this method of analyzing work the credit of the greatly increased performance on small assembly and machine work. Others have found it of value in eliminating waste of time and effort in the preparatory and "clean-up" work incident to manufacturing operations.

Motion-picture recordings of time and motion studies are proving valuable to those companies which control numerous factories throughout the country. These films show the slower plants how they can improve their operations to match the efficient plants, and thus pave the way for job standardization.

One of the most pressing problems in business or industry is to evaluate the work of individual employees, not only with regard to compensation, but also in connection with organization, overhead, promotions, and general efficiency. In one case 8000 positions were analyzed, classified, and the classes

[9] National Industrial Conference Board Memorandum No. 20, Jan. 5, 1934.

[10] *Monthly Labor Review*, May, 1934.

[11] *Monthly Labor Review*, August, 1934.

[12] *Factory Management and Maintenance*, December, 1933.

[13] *Engineering*, May 25, 1934. MECHANICAL ENGINEERING, August, 1934, pp. 493–494.

graded. Standard minimum and maximum salaries were determined and definite objectives set for ambitious employees to work for, instead of expecting promotion merely on a service basis or personal equation.[14]

WASTE ELIMINATION

There has been little opportunity for a broad-scale aggressive program on waste elimination during the past year, simply because of continued subnormal activities throughout the industries and the more or less quiescent state of the technical and other societies which represented them.

In the plant, attention is now being given to getting the waste from expense material under control. Closer cooperation is being effected with the standards division in the development of methods for ordering and specifications for such materials—with the result that the advantages of quantity purchasing have also been realized. Furthermore, in these stringent times the appeal of money waste to the worker through comparative costs has been increasingly effective.

Greater effort has been made to reach people in less formal ways than in other years. The subject has been presented before community and women's clubs and other social gatherings with surprising success, evoking an interest which few other subjects can command. This was evidenced not only by the discussion that followed but also by the avidity with which material available for distribution was taken away.

It is becoming more widely recognized that accident prevention should not be merely a matter of installing mechanical guards and sponsoring safety campaigns. Any well-developed safety program will only bring results when such factors are taken into account as minimum labor turnover, good health, high morale, good working conditions, correct personal habits, and proper education not only as it applies within the confines of industry but in the home and public places. Worry from fear of poor health, poverty, and unemployment has been found to be one of the chief causes of accident. Increasing attention by the proper authorities should be given to raise the general standard of health, not only of men and women, but also of children of school age.

Finally, the importance of a suggestion system is being forced even more strongly upon the minds of plant managers as a means of waste elimination. It has assumed such proportions in recent years that space elsewhere in publications of the Society will be devoted at some length to this subject.[15]

QUALITY CONTROL

As a natural outcome of business depressions and a greater uniformity in prices for standardized commodities, quality has been pushed to the forefront in the last few years as the one distinguishing mark to differentiate the products of several manufacturers in the same field. Quality control, heretofore, has largely centered around the function of inspection following manufacture as a means of weeding out defective units and aiding in the proper operation of wage-incentive systems.

It is now being recognized that quality is an essential consideration in every activity of business and its control demands the cooperation of every one in the organization. In the first place industry must look to the customer as the originating source of quality and it is the task of the sales and merchandising divisions to translate his desires into the attributes of the product. In the second place the engineering division is called upon to interpret these specifications rigidly and develop from them a proper form for the product and a suitable process for its manufacture. If qualities are required which cannot be obtained with available materials or combination of known devices, the research division must discover how such qualities can be built into the product. In the third place, manufacture should be so conducted that the requisite degree of quality will be consistently maintained. Finally, the purchasing division must give attention to the run of quality as it comes from each source of raw material along with price and other usual considerations in order to buy only materials for which quality is known to be in control. Otherwise, unavoidable variations in quality of the final manufactured product will be introduced. Thus, a quality consciousness is incumbent upon every business executive.

Quality control is, therefore, taking on a new meaning to industry and more effective methods are being tried out by different companies to establish fully requirements and eliminate the causes of variations. To a large extent the methods now in use are dependent upon statistical technique; however, recent study shows that practical procedures can be devised as soon as assignable causes for variation have been discovered for maintaining quality within prescribed limits of control. Once quality has been standardized, these practises will permit a reduction in the cost of inspection. The diversity of application has been from interchangeability by parts to the economic selection of inspectors.

Several valuable papers on this subject have appeared in the last year in the publications of the A.S.T.M. and other American and European technical publications. The Industrial and Agricultural Research Section of the Royal Statistical Society of England has been particularly active and announced a supplement of its *Journal* dealing almost entirely with the development of this new tool, to begin this last summer.

Professors in four American universities have in their regular classes discussed the general theory of quality control and the application of statistics in engineering and manufacturing. Many industrial investigations such as those carried on at the Mellon Institute of Industrial Research have applied to some of these same statistical methods.

Of the consumers the automotive industry has taken the lead in getting producers to control their products. Economic quality control is the real answer to the buyer's specification problem.

One of the greatest needs is to bridge the gap between the technical language of the statistical theory and the practical application by the engineers and foremen. Another need is to show to executives the great advantages to be gained by the use of these control methods so that they will permit their engineers and foremen to attempt control in the manufacture of their own products.

RESEARCH

During the past year research has continued to be the source of technological advance for many industries and has brought forth new profit opportunities which only await realization with the revival of business. Though research appropriations were of a sort that would be pared down early in any period of retrenchment, many projects have been continued because of their ultimate benefits. Under the pressure of necessity and progress, management research has been extended into other fields, particularly that of distribution, in order to establish greater control over sales effort, to find the most profitable customers, and to place better products on the market.

Several important research projects have been conducted in the field of management. Prof. Elliott Dunlap Smith, of the Institute of Human Relations at Yale University, has completed

[14] *Personnel*, February, 1934.

[15] In this connection see papers on suggestion systems in the November issue of MECHANICAL ENGINEERING, and elsewhere in this issue.—Editor.

the first of an extended series of studies on human problems of technological change.[16] From a survey of the recently introduced "stretchout" in the textile industries it is evident that a method's change has more far-reaching effects than one involving labor-saving devices, and causes more human and economic distress when introduced abruptly on a large scale than would be the case if the same results were obtained less spasmodically.

Prof. North Whitehead has completed an exhaustive analysis of the work of Pennock and Putnam at Hawthorne for the Western Electric Company in an attempt to bring out qualitatively the major factors in motivation among industrial workers. The research had as its aim a better understanding of the operatives' working habits and attitude. These studies are typical of the increased amount of research into problems of employee relationships which are being conducted in the field of psychology and are of major importance to management as set forth in the paper by Dr. Likert at the 1933 Annual Meeting.[17]

Engineers have made their contribution to industrial economics as exemplified by the studies of T. M. McNiece on "Rhythmic Variations in Industry,"[18] and Prof. Walter Rautenstrauch on "Economic Characteristics of Industry."[19] McNiece demonstrates that the cycles of replacement for commodities which become more pronounced as they approach the characteristics of durable goods are a means of propagating economic disturbances and that major depressions occur when all cycles are in phase downward. Professor Rautenstrauch has brought to light the relative significance of the costs to obtain, to own, and to operate the productive facilities of enterprises in industries having differing requirements for complex equipment. The partially completed studies of W. H. Halbrooke lead naturally from this last into a better understanding of what constitutes a proper financial structure for an industry.

With the greater complexity of factors which confront the chief executives at the present time and the narrower profit margins, more exact means of control are required. Statistical technique can be employed to provide these controls as shown by the recent studies of Dr. W. A. Shewhart and Prof. T. H. Brown.[20] The former has not only developed techniques for quality control of general significance to management but also through a subcommittee of the society has carried forward similar statistical applications into the field of engineering. The latter has evolved means of control for problems in distribution where the governing factors are distinguished solely by attributes and where the usual means of separation according to some logical scale of measurement are inapplicable.

Following the renewed interest in motion study aroused in the last few years by Allen H. Mogensen and others, a group of experts has been recently organized to promote further research of a fundamental nature into problems of work simplification and motion economy, and to coordinate studies now being carried on in various universities as well as in industry.

In reviewing the outstanding activities of research in the field of management it must be remembered that research is an essential characteristic of the work of every progressive managing executive in American industry. Few would readily admit that their daily contributions of new ideas to better management methods for their individual companies were in the nature of research; however, when progress in management is measured over the years, the greater part of the advance can be attributed to this one source.

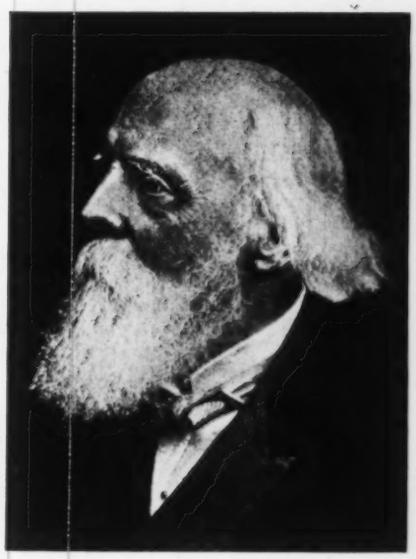
[16] MECHANICAL ENGINEERING, February, 1934.
[17] Ibid, April, 1934, pp. 203–206.
[18] Ibid., November, 1933, pp. 659–666.
[19] Publication of recent findings to be forthcoming shortly.

[20] Presented at the Annual Meeting, December 3 to 7, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. See also elsewhere in this issue.

Galloway, N. Y.

CHARLES H. HASWELL

A. JAY DU BOIS



CHARLES T. PORTER

EARLY U. S. STEAM TABLES

A Historical Summary of Tabulations Published in This Country Prior to 1921

By ARTHUR M. GREENE, JR.[1]

I HAVE been asked to speak of the early steam tables produced in the United States and I turn at once to that published in Nystrom's (John W. Nystrom) "Pocket Book" of 1866. After two pages on specific caloric (specific heat) he gives four pages devoted to the properties of saturated steam and water from a pressure of 1 lb per sq in. to 150 lb per sq in. by one-pound intervals. This table and one on properties of water had been calculated earlier by Nystrom, while under the direction of Chief-Engineer Isherwood of the U. S. Navy, and had been enlarged and rearranged for the "Pocket Book."

At each pressure, Nystrom gave the temperature of boiling and the units of heat per pound and per cubic foot from water at 32 F as given by Regnault's formulas of 1847. The specific volume of steam was computed from the work of Fairbairn and Tate of 1860. The units of heat of the water per pound above 32 F at different temperatures came from a parabolic formula derived from Regnault's experiments, while the volume of the water was derived in terms of the volume of pounds of water at 39 F by a formula involving powers of $(T\text{-}39)$, the origin of which he does not mention. He expresses volumes of steam in cubic feet per pound as well as in volumes of water at 39 F.

Charles H. Haswell gives in his "Pocket Book" of 1867 (page 524) twelve values of latent heat and the sum of sensible and latent heat at temperatures varying from 32 F to 410 F, using results of Regnault. Another table lists pressure, volume, and density corresponding to different temperatures. The formula of Pamborn and that of Pole and Tate were used for volumes in terms of water volume. His formula for pressure, based probably on Mellet, is $\left(\frac{t+100}{177}\right)^6 = p$, where t is in degrees fahrenheit and p is in inches of mercury. He compares his pressures with those of experiments of a committee of the Franklin Institute and states that there is some difference between his values and those of the committee.

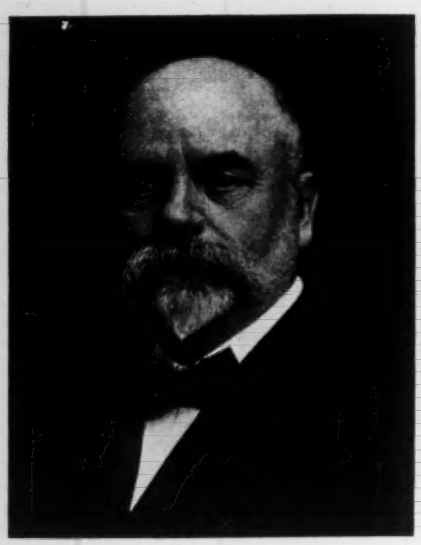
In the third edition of "The Richards Steam Engine Indicator," by Charles T. Porter, dated 1874, steam tables are given. These were based on the work of Regnault, for pressure, temperature, and total heat; the work of Rankine for specific volumes below 16 lb, while the work of Fairbairn and Tate was used for other volumes. The earlier editions gave specific volumes determined by the perfect-gas law. The specific volume of the liquid is given up to 100 C from values of Kopp.

The tables give pressure, temperature, heat in the water above 0 F, heat of vaporization, total heat above 0 F, ratio of volume of steam to water, weight of one cubic foot of steam in pounds, and weight of steam relative to air at 32 F and atmospheric pressure. There were three tables extending from 32 F to 213.03 F, from one pound to 210 pounds per square inch, and from one-fourth atmosphere to 18 atmospheres. The thermal unit was based on one pound of water and one degree rise at or near the freezing point. J was taken as 772 ft-lb.

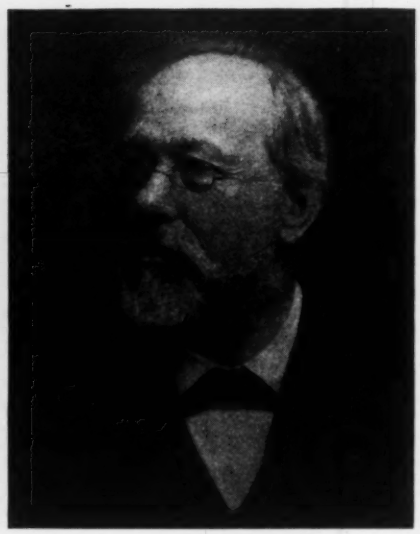
The Porter tables were the standard recommended in 1890 by the A.S.M.E. Committee on the Trials of Pumping Engines.

In 1878, Prof. A. Jay Du Bois, of Yale, translated part 2 of volume 2 of Weisbach's "Mechanics of Engineering." This part covered heat, steam, and the steam engine. He inserted a steam table prepared by Richard H. Buel, C.E., a graduate of

[1] Dean, School of Engineering, Princeton University, Princeton, N. J. Mem. A.S.M.E. An address delivered at the Third International Steam Table Conference, New York, N. Y., September 19, 1934.



CECIL H. PEABODY



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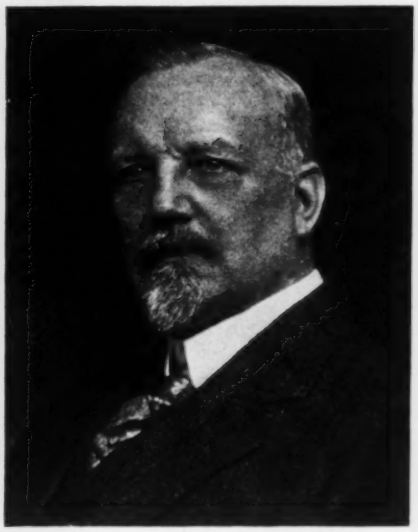

WILLIAM KENT

the Rensselaer Polytechnic Institute, class of 1862. Buel probably studied Rankine's "Steam Engine" and was guided by this study in the formulations for his table. This table contains the following properties: Pressure in pounds per square inch, from 1 to 1000, temperature in degrees fahrenheit, heat of water from 32 F to T, internal latent heat, external latent heat, latent heat of evaporation, and total heat of evaporation in Btu per pound, total heat in units of evaporation, weight of one cubic foot of steam, volume of one pound of steam, and ratio of volume of steam to volume of water at maximum density. The formulas by which the quantities were computed are given at the opening of the table. He used Regnault's experiments for pressures and temperatures to 446 F and then used the Rankine formula (1849) for higher values of temperature. To determine volumes he used the Rankine method of finding the ratio of the latent heat per pound to the latent heat per cubic foot, and compared these results with those of Fairbairn and Tate (1860). The formulas of weights and volumes of water at different temperatures were taken from Watt's "Dictionary of Chemistry." These were based on experiments of Kopp, Matthiessen, Sorby, and Rosetti. For the total heat of steam he used the Regnault formula (1847), and for the heat of the liquid he used the Rankine formula (1851), based on the Regnault experiments. He then computed the external work of vaporization, using 772 as Joule's equivalent. His thermal unit probably referred to one pound of water and one degree rise at temperature of maximum density, as he followed the teaching of Rankine.

Du Bois translated Roentgen's Principles of Thermodynamics in 1880 and in the second edition of 1889 he added the steam tables of Zeuner and those computed by Buel which have been described.

In 1888 Prof. Cecil H. Peabody, of the Massachusetts Institute of Technology, prepared a set of steam tables to be used in connection with his notes on thermodynamics, which later became his most excellent treatise on this subject. His tables were based on the best and most recent data of that day. His pressure-temperature columns were computed from the Regnault data by a new formulation of the equation which was then compared with the p-t equation of Rankine. From that new formulation he obtained the differential coefficient for use in the Clapeyron relation. For the heat of the liquid and the specific heat of the water he used the data of Regnault and Rowland, and used as the Btu the heat per pound of water from 62 to 63 F. For the mechanical equivalent of heat he used the value 778-ft-lb. For the total heat of steam he used the Regnault expression, and the volume of steam was computed by the Clapeyron relation. He compared the volumes with values given by the Tate and Fairbairn experiments, and although there was a great difference he preferred to use his formulations. For water volume he used the formula given by Hirn. This table is the earliest American table known to the author in which the entropy of the liquid is given. It was computed by the use of the various specific heats of water determined by him. The entropy of vaporization was not tabulated. This table was used by Professor De Volson Wood in the third edition of his Thermodynamics of 1889.

In 1889 Dwelshauvers-Dery, of Belgium, presented his steam table before The American Society of Mechanical Engineers.

Kent, in the earlier editions of his "Handbook," published in 1895, used the Porter tables with the Dwelshauvers-Dery tables for volumes and the Buel tables for relative volumes up to 220 lb per sq in., and from 220 lb to 1000 lb he used the Buel tables for all values.

Supplee, in his "Reference Book" of 1903, followed Nystrom's table to 446 F and then extended it above this point where it was found to agree with the values deduced by Macfarlane Gray.

In many of these early tables and in texts of this time the specific heat of superheated steam was considered to be constant and taken as 0.48.

At the meeting of The American Society of Mechanical Engineers in Richmond, Va., in 1890, Robert H. Thurston, professor at Sibley College, Cornell University, past-president of The American Society of Mechanical Engineers, and formerly a professor at Stevens Institute of Technology, discussed the committee report on duty trials of pumping engines. In the course of his remarks he made the following statement which I wish to quote:

> The adoption of the tables of steam-pressures and temperatures by the Committee, from Porter on the Indicator, gives rise to the question which always presents itself on such occasions: Of the many sets of tables now available, which is the most accurate, and which is on the whole best adapted to this work? Mr. Porter's well-known exactness and care and the fact that he obtained his figures originally directly from Regnault, make it seem probable that they are perfectly reliable.

L. S. MARKS

HARVEY N. DAVIS

G. A. GOODENOUGH

But the handy and often-quoted tables of D. K. Clark, those of Nystrom, those of Haswell, and others of the older dates, differ in small degree usually, but enough to make it wise to select some one as standard; while the later work of production of more elaborate tables has given rise to still others which we would all, I presume, like to be able to use with confidence. I have used those of Buel in my own books and in some of my other work. Their author was very exact in his habits of work and gave us, for the first time, all that the engineer desires to find in such tables. The latest of these tables, those of Professor Peabody, are beautifully printed and conveniently published and are, so far as I have been able to check them, apparently very accurate. There are, nevertheless, discrepancies throughout the whole list of authors, and it would be a great boon to the engineer to secure such a comparison of authorities, so-called, as would determine definitely the extent, reason, and effect of such discrepancies, and the relative accuracy and value of the several tables for his purposes.

Professor Thurston had translated Carnot's writings and those of Regnault and knew the thermodynamic implication of tables.

In the discussion of this same report, Prof. D. S. Jacobus, of Stevens Institute of Technology (president of The American Society of Mechanical Engineers, 1916) tabulated the values of pressure, latent heat, total heat, and volume at four temperatures from the tables of Regnault, Porter, Clark, Dwelshauvers-Dery, and Peabody to show the variations in the values of these quantities. He placed greater reliance on values computed by thermodynamic laws than the values determined directly by experiment.

In the two decades following the year 1890, a great number of investigations, well known to all of you, were made in Europe and America, giving more extended data regarding the properties of steam and water, and as a result of these the steam tables of Marks and Davis appeared in 1909 and a new table by Peabody in the same year, although in 1907 Peabody had made a revision and enlargement of his earlier tables.

Marks and Davis used their own able formulations based on the use and adjustment of data from the experimental work of American and European investigators. These tables gave temperature, pressure, density, volume, heat of liquid, latent heat of evaporation, total heat of steam (enthalpy), internal energy of evaporation, and of steam and entropies of water, of evaporation, and of steam in both the saturated and superheated regions. The tables were carried to the critical temperature in the saturated region and to 600 F superheat and 600 lb per sq in. in the superheated region. A separate table gave the increase in total heat and in entropy above 600 deg superheat from 700 to 2000 deg of superheat for thirteen different pressures; and another table gave the thermal properties of water. For use in the Clapeyron relation the mechanical equivalent of heat was taken as 777.52 ft-lb. The Btu was defined as "1/180 of the heat needed to raise one pound of water from freezing to the boiling point."

In 1909 Peabody revised his tables by formulations obtained from the review of all experimental steam data and the work of Dr. Harvey N. Davis, and tabulated the same properties as those given in the Marks and Davis table, except the total heat of steam and the entropy of steam. The table extended to 428 F in the saturated region. Saturated and superheated steam properties of quality, volume, heat content, pressure, temperature of saturation, and entropy were given in Peabody's most convenient temperature-entropy table up to 308.5 lb per sq in. and to 698.2 F in temperature.

In 1912 Smith and Warren (Great Britain) published through Van Nostrand a steam table which, according to Goodenough, follows closely the formulation of Mollier used in the tables of 1906 and work of Callendar.

In 1914 Goodenough published his bulletin on the thermal properties of steam (Bulletin No. 75, Engineering Experiment Station, University of Illinois), in which he reviewed the experimental work on water and steam and the papers and treatises on theoretical thermodynamics from those of Regnault in 1847 to the papers of Heck and of Callendar of 1913. His aim was to improve the past formulations for the computation of tables which would be more consistent and more accurate than those which had been developed previously. He deduced ten basic equations for the determination of the properties of steam in the saturated and superheated condition. In 1915 he published his steam tables using these formulas and tabulating with the thermal properties the enthalpies of water and steam in place of the heat of the liquid and total heat. His saturated steam tables gave pressures, temperatures, volumes, densities, "heat contents" of liquid and dry vapor (enthalpies), heat of vaporization and internal latent heat, energy of vapor and entropies of liquid, of vapor, and of vaporization. One table extended to the critical temperature. Separate tables of superheated steam to 800 lb per sq in. and 950 F were included

(*Continued on page 764*)

CONTROL *of* DISTRIBUTION

A Discussion of Statistical Methods, With Illustrative Examples

By THEODORE H. BROWN[1]

THE PROBLEM OF STANDARDS

IN ENGINEERING practise the use of standards has become fixed so firmly that it may be considered an automatic part of the every-day work of the engineer. Standards in production, standards in material, standards in design, all are accepted as a matter of course. In the writings of accountants the use of standards in comparative accounts or in the interpretation of accounts at least is implied. In the field of management, however, where statistical control might be of great value to the business executive, the use of standards still represents a novel approach. Unless the necessity for standards is accepted and unless a knowledge of the methods of building them is understood, many of the problems of business, particularly those in the field of distribution, must continue to involve large accompanying wastes.

No sane manufacturing executive would think for a moment of making an appropriation of $50,000 to locate some loss or waste in the production process without having a fairly precise understanding as to how the money was to be spent and a fairly confident feeling that a saving would result from the expenditure. Nevertheless, these same executives have been known to risk $50,000 and more in market investigations without having the remotest idea how the money was to be spent, or what chance they had of ever recovering even a small fraction of the expenditure through an increased knowledge of markets.

To select but a single illustration from many which might be cited, manufacturer *A* who distributed a certain food product chiefly in the Middle West found himself faced with competition from a lower priced product of a somewhat different quality which purported to give the purchaser the same food value. Very naturally manufacturer *A* in his desire to estimate the effect of this competition consulted an advertising agency. These agents made a survey of the conditions by the sampling method of market analysis. Unfortunately, however, after the work was completed and tables were compiled, no knowledge of how standards should be set up was available. The result was in effect that the agents reported to manufacturer *A* that they *guessed* the conditions were about so and so. The manufacturer acknowledged that they might be right, or at any rate on the basis of the large cost of the survey he acknowledged that this expensive toy must have *some* value in it, and consequently made a guess change in policy to meet the competition.

It is to be noted that in this case, details of which have been concealed for obvious reasons, both the advertising agency and the manufacturer were lost amid difficulties because there was no standard by means of which they might have even a remote chance of knowing the significance of the facts.

THE PROBLEM OF THE TYPE OF DATA

The report to manufacturer *A* contained tables which classified for each of several market districts the sales not only of manufacturer *A*'s products but also those of the competing brands including those of the new competitor. Obviously, conclusions from such a table would be drawn by associating the figure given in each cell of the table with those given in the other cells. The relationships thus established would be the significant ones which were sought. Because of his scientific training the engineer might desire to draw curves of relationship. These, however, would be valueless because there is no numerical order or relationship that would classify one district in relation to another or one brand in relation to another. Obviously, then, these are quantities which differ essentially from those with which the engineer is familiar. We may designate them by the term "attributes" and defer temporarily a more exact description, together with methods of setting up standards, until certain other ideas are in hand.

The foregoing illustration is but typical of many which might be cited. The problem, therefore, becomes centered at once upon the question of determining, first, what statistical methods or approaches should be used in order to set standards in certain common types of problems, and second, whether the statistical methodology as now known is sufficiently comprehensive to meet these problems. A review of the common methods, consequently, is appropriate.

A REVIEW OF STATISTICAL METHODS

The statistical methods commonly taught in our schools and colleges, as well as the statistical summaries presented by the economist to the public in government reports, on the financial pages of the newspapers, or in trade magazines, may be called the "statistics of variables." The term "variables" is used to indicate that the methods have been designed and applied to quantities which change from condition to condition. The engineer is quite familiar with such quantities. In general, they comprise those which can be measured. Such quantities refer either to the size, the mass, or the time which has been measured. The measurements may be taken either of people or of things. Possibly the term should be changed from the statistics of variables to the term "statistics of measurement." Moreover, these measured quantities are familiar also to the engineer, since they comprise the basic units out of which the "dimensions" of various other physical or engineering formulas are built up. We shall see presently that the statistics of variables is not the only group of statistical data in which business is vitally interested.

The basic concept in the analysis of statistics of variables is the frequency distribution. As commonly presented, this represents merely a method of grouping or sorting statistical items into broad classes. This is done for the convenience of certain computations. The basic concept of the frequency distribution then is used as a basis for building up the method of index numbers; the method of time-series analysis within which is included the determination of a trend line, the determination of seasonal fluctuations, the calculation of the residual cyclical changes; and finally its use in relating one variable to another in correlation studies.

[1] Professor of Business Statistics, Harvard University, Cambridge, Mass.

Contributed by the Management Division and presented at the Annual Meeting, December 3 to 7, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

In all of these methods of analysis, or summarization of data, the economist is attempting to measure economic forces. Thus, he conceives the trend line as measuring the economic force of long-time growth. However, for the individual business this may be altered radically by an executive decision so that the concept of economic force is invalid. A similar statement may be made in regard to the measurement of seasonal variations. Finally, every one recognizes the difficulties which the economist has had in the measurement of the forces which cause the changes in general business conditions.

Recent difficulties in the interpretation of index numbers picturing the national economic situation are illustrative of the problems in the proper use of such indexes. In such cases the technical difficulties are increased by reason of the use of indexes for economic studies.

Finally, the idea of the relationship of one statistical quantity to another seems to be one of those concepts which appears continually in connection with business problems. Yet the fact remains that it is exceedingly difficult to find in business practise good examples where correlations actually would be of advantage. The conclusion must be reached, therefore, that from the point of view of business practise either the method is overcumbersome or some fundamental factor has been neglected so that the method does not apply directly.

Returning now to the question of the frequency distribution, we may find that the device is of fundamental importance if the calculation of an average be thought of as a process of determining or fixing a standard. The use of the device in this way is a common one in connection with problems of production, since the selection of either an arithmetic average, a median, or a modal value often is made in time studies to select a standard against which an operator must work.

Comparison of the results with the standard, however, raises immediately the question of limits. Manufacturing limits or tolerances are common in the every-day work of the manufacturing engineer. The maintenance of quality in a manufactured product inevitably involves this idea of tolerances expressed in a statistical form, using as a base the frequency distribution. In very general terms this is the basis upon which Shewhart has developed his researches in this field. In some of the examples which we shall consider later, a study is made of the variations from an arithmetic average to be found in data grouped in various ways. Out of these variations for certain cases may be derived the equivalent of an experimental error. Variations in the other groupings of the data then are studied in relation to this in order to determine whether they are significant.

METHODS FOR ATTRIBUTES

From the foregoing discussion it will be seen that the business man requires a method of setting standards for certain classes of problems. It has been indicated also that the statistical methods as commonly used and frequently presented by economists are usually organized for and interpreted in terms of economic forces rather than for use in making comparison with standards. More important than this, the methods deal largely with variables, or, in other words, with quantities which may be measured. Consider now quantities which simply are counted.

If a person or thing possesses a certain quality or characteristic, it is termed an attribute of that person or thing. Thus, in the field of distribution, a radio manufacturer would like to know in a given market area the number of families which possess a radio. Determination of this number is not made through a process of measurement. It consists simply of a process of counting. The illustration may be generalized. In the field of distribution the number of units of a given article which has been sold is indicated by a simple process of counting. This statement recognizes that it makes no difference whether the counting process is made by some procedure of census taking or whether the counting process is made through the shipping room of a manufacturer. Another large group of problems with which the executive is concerned intimately is to be found in the circulation of newspapers and magazines. This is important because these newspapers and magazines represent the media by which the sales executive tells the market about his goods. Here such questions as those of coverage, of duplication of circulation, and other similar questions are of vital importance if money is to be expended wisely.

The importance of the count of the number of things representing an attribute goes even deeper. Take, for instance, the case of a manufacturer of electrical appliances. The number of units of each appliance which he sells consists essentially of a count of an attribute, each attribute being represented by each model. The economic procedure for handling such data is to convert the sales prices into dollar figures, and simply because the dollar figures represent similar accounting units to combine the total for each group into a grand total. Then by plotting the total sales for each month, or for other accounting periods, analyze the data as if they were variables. Surely such a procedure is inconsistent with sound business control.

AN ILLUSTRATIVE PROBLEM FOR ATTRIBUTES

In the setting of standards for a single attribute we may use as an illustration the figures published by the Providence Journal Company. This company publishes both a morning paper, known as the *Journal*, and an evening paper, known as the *Bulletin*. The circulation figures as checked by the Audit Bureau of Circulations for six months ending March 31, 1931, were as found in Table 1.

TABLE 1 PROVIDENCE NEWSPAPERS

	Coverage	
	Number	Per cent
Total families	149,500	..
Evening Bulletin	84,200	56.3
Morning Journal	39,000	26.1
News-Tribune	31,300	20.9
Coverage omitting duplication		
Bulletin—Journal	101,000	67.6
Bulletin—News-Tribune	98,000	65.6
Calculated values from data		
Theoretical overlap, *Bulletin—Journal*	21,960	
Actual overlap, *Bulletin—Journal*	22,200	
Theoretical overlap, *Bulletin—News-Tribune*	19,820	
Actual overlap, *Bulletin—News-Tribune*	17,500	

The standard of comparison for individual papers, obviously, is the total number of families in the state. The percentage of coverage indicates the number of families receiving each newspaper expressed as a percentage of the total potential. If the total circulation figures were not known or if sub-groups had been determined through a sampling process, this percentage could not be considered exact but subject to some error. We shall consider presently how this may be tested.

In the case of other problems the comparison of attributes may not be made with total potential as a base, but rather with a similar figure which is available for another corresponding period. This period often will coincide with the accounting periods used for accounting controls.

There often arises a further difficulty which must be guarded

against. This occurs when the attributes counted do not consist of a single homogeneous group. For example, in the case cited for the manufacturer of electrical appliances the figure showing the total number of appliances shipped during one-quarter of this year in relation to the number shipped during a corresponding quarter in a previous year might be exceedingly misleading. Complete interpretation would come through a comparison of two or more ratios. The ratio might remain the same, yet changes in the numerator and denominator be vital and significant, or the ratio might appear to change radically and yet comparatively few significant changes may actually have taken place.

THE ASSOCIATION OF TWO ATTRIBUTES

Table 1 relating to the *Providence Journal* also includes the question of overlap of circulation. This is a problem which is often of vital significance. It is essential to know whether such an overlap is greater or less than that which we should expect. The process of setting a standard for such a case introduces no complex mathematical problems. It involves only a simple equation similar to that found in the use of a pair of dice. It we consider a single die the chance that we will get an ace may be represented by the fraction $^1/_6$, since one face can be considered a success out of the six possibilities. Similarly, the chance that a single family of the 149,500 families in the state of Rhode Island actually buys the *Bulletin* is 84,200/149,500. In the case of the second of our pair of dice the chance of getting another ace is exactly the same. Similarly for the *Journal*, the chance that a family selected at random would purchase the *Journal* is 39,000/149,500. For two dice the chance that both will have aces face up is the product of the two chances or, in other words, $^1/_6 \times {}^1/_6$. Similarly, the chance that a single family selected at random will buy both the *Journal* and the *Bulletin* is the product of the two fractions given. This is equal to the pure chance overlap, or 84,200/-149,500 × 39,000/149,500. This expression which is equal to the chance overlap has the value $x/149{,}500$, where x is the calculated number of families. We may then express our result in the form of an equation, $84{,}200/149{,}500 \times 39{,}000/149{,}500 = x/149{,}500$, or $\dfrac{84{,}200 \times 39{,}000}{149{,}500} = x$.

The value x is a number which is entirely free from bias one way or the other, and simply represents pure accident. This calculated value of x, which is used as a standard, may or may not be the same as the observed value. If the actual overlap is less than this number and if this difference is sufficiently large to be significant in relation to the size of the sample, people tend to avoid the purchase of both papers. On the other hand, if the actual number is greater than the standard, then apparently people find that the purchase of two papers brings a sufficient added quantity of news to their homes to warrant the additional expenditure. These two conditions are very similar to a pair of dice, assuming that the dice are loaded. The loading, in other words, corresponds to the market influence which is not without its interesting counterpart in games of chance presumably conducted without control.

The last four items in the table show how the figures actually work out. It is to be noted that the agreement between theoretical and actual overlap of the *Bulletin* and *Journal* is very close. The actual overlap is 1.1 per cent greater than the standard or theoretical overlap. In the case of the *Bulletin* and *News-Tribune*, however, the actual overlap is less than the theoretical. This actual overlap is 88.3 per cent of the theoretical standard. It indicates quite a strong tendency on the part of the purchasers of the two papers to buy one but not both. The coverage figure on the basis of the theoretical instead of the actual for the *Bulletin* and *News-Tribune* is 64 per cent of the total number of families. Apparently the *Bulletin* and the *News-Tribune* reach distinctly different groups of readers.

In many cases, especially in marketing investigations, the count of the attributes cannot be made complete because of the expense which is involved. In such cases the information is based upon a sample of the whole which has been taken. Obviously, this introduces in the resulting percentages the possibility of chance variation because of the peculiar selection of the sample. In such problems two situations may arise. One occurs after the sample has been taken and the analysis of the results obtained. In such cases it may be presumed that the number of items in the sample has already been fixed so that in consequence the only thing that is necessary to determine is the accuracy of the results obtained. The other case arises in the planning of market surveys. If some estimate can be made of the chance of a case selected at random falling definitely into a given category, then the number of cases to establish the results with a given degree of accuracy may be estimated. This is a great help in connection with market surveys where the continual habit of the advertising agency is to carry through the test with an ample number of cases in order that they may be sure to get a sufficient accuracy in the results. The difficulty in this procedure is that the advertising agencies seldom know how to determine the accuracy of their results after they have been found.[2] Cases have been known where many thousands of dollars have been spent on marketing surveys when all desired information could have been developed for the expenditure of one or two thousand dollars. It is to be assumed, of course, in the sampling investigations that the sample taken shall be a random one, for otherwise the cases selected might be exactly those which would appear to prove any predetermined objective selected.

Up to the present point we have considered the fundamental question of standards, reviewed the methods of statistical analysis commonly taught and found them inadequate. We have developed the need for standards covering statistics of attributes, and have indicated how some of these standards might be developed. There remains for our present purpose consideration of the very powerful statistical tool known as cross-classification.

ANALYSIS OF CROSS-CLASSIFICATIONS

One of the examples cited at the beginning of this paper covered the case of a manufacturer who was seeking market information through his advertising agency. Apparently this agency classified the sales of several similar brands of food for each of several geographic districts. Presumably the table might be arranged so that the sales for each individual brand would be indicated on a given row of the table of figures, while the figures in any given vertical column would represent sales for a particular geographic district. Such a cross-classification may be described briefly as sales of brands by geographic districts. Such cross-classifications are common to many business problems.

The cross-classifications indicated may apply to data which represent either variables or attributes. Three possible combinations appear: Classifications of (1) variables by variables,

[2] An article on page 218 of the September 1, 1934, issue of *Sales Management* presents opinions of a number of advertising and sales executives concerning the adequacy of a sample. The variations in replies indicate that there is no plan of attack on the problem commonly recognized by business.

(2) attributes by variables, (3) attributes by attributes. The analysis of the first of these three possibilities is a correlation. Every engineer is familiar with the plotting of dots on a piece of cross-section paper representing observations. He is also familiar with drawing a line which seems to represent a relationship between the two variables that he is studying. This line, known as the line of relationship, may be adjusted either by the method of least squares or by a purely visual process using a curved ruler. In the other two cases enumerated the methods commonly presented are not applicable because there is no way of arranging the different qualities of a different attribute in an order which represents a numerical relationship between them. Thus, in our example there is no logical way of arranging either brands of a given food or geographic districts of the country in an order which will have a numerical relationship. This is, of course, the condition that characterizes an attribute. It does not possess per se any measurable characteristic. It should be noted, of course, that this is not to be confused with certain measurable features which a given attribute may possess. Thus, a brand of food may have a certain volume per pound of weight which will vary slightly from sample to sample. It represents a variable but it does not represent the quality which caused the purchase of the food. For problems such as these the recent research work of R. A. Fisher[3] in the field of biological science and its apparent usefulness in agricultural experimental studies suggest wide possibilities for the use of the method in business.

Fundamentally, the method of R. A. Fisher provides an analysis of each portion of a cross-classification table, such as that already indicated. The process consists of a study of the variations from the average, first for the rows, then for the columns, then for an interrelation between the figures, and finally for the table as a whole without consideration of any classification. The measure of these variations is taken as a square of the standard deviation. This is known as the variance. Fisher also has introduced a value known as the mean variance which involves a consideration of the number of items in hand. In a cross-classification table this would reflect the number of rows or the number of columns. Its importance lies in the fact that it allows for a relatively small sample, thus making it possible to analyze tables of figures with relatively few columns or rows.

For an illustration of a simpler form of the method of approach the following example may be used.

A study of public opinion of radio instruments in 1933 was developed in part through the use of a sample of approximately 2500 interviews with radio owners. These interviews were scattered over four major sections of the country.

One of the tables derived in the investigation indicated the opinions in regard to improvements shown in various makes of instruments. These data were obtained to disclose opinion as to the most progressive manufacturers. This table as first compiled was as shown in Table 2.

TABLE 2 MOST PROGRESSIVE RADIO MANUFACTURERS

	Northeast		Mid-West		South		West	
	No.	Per cent total	No.	Per cent total	No.	Per cent total	No.	Per cent total
Manufacturer 1...	155	29.8	365	41.9	206	41.0	263	39.1
Manufacturer 2...	198	38.1	223	25.6	140	27.9	152	22.6
Manufacturer 3...	89	17.1	209	24.0	119	23.7	191	28.4
Others.....	11	2.1	29	3.3	10	2.0	8	1.2
No choice.....	67	12.9	45	5.2	27	5.4	58	8.7
Total.....	520	100.0	871	100.0	502	100.0	672	100.0

[3] "Statistical Methods for Research Workers," by R. A. Fisher, Oliver and Boyd, London.

It will be noted at once that the figures given in Table 2 vary from manufacturer to manufacturer. There are also large variations to be noted between the sections of the country from which the interviews were taken. From the point of view of those conducting the survey it was necessary to know whether each section of the country represented a market condition which should be considered as requiring a separate standard or whether a single standard might be taken for the country as a whole. As far as different makes of instruments are concerned it would seem from the inspection of the table that the variations were so great that certainly the differences noted might be considered significant.

Pertinent to the writing of the final report the problem as stated raises the question of whether the classification of the table as organized has been carried to too great an extreme. In other words, should there be in place of four groups of figures only a single group representing one column showing the number of interviews and a second column showing the percentages?

The method of analysis used is that of variances. The term "variance" is applied to the square of the standard deviation multiplied by the number of terms involved. Thus if

σ = the standard deviation
n = the number of items
$n\sigma^2$ = the variance = V

For the special case of the table which follows, let

x = any number in Column 1
y = any number in Column 2
z = any number in Column 3
w = any number in Column 4
u = any number in any column
n = the number of figures in each column
m = the number of columns

Then for Column 1

$$\sigma^2 = \frac{\Sigma x^2}{n} - \left(\frac{\Sigma x}{n}\right)^2$$

See "Laboratory Handbook,"[4] pages 109 and 193.

Therefore

$$n\sigma^2 = \Sigma x^2 - \frac{(\Sigma x)^2}{n}$$

This is called the variance V. Similarly the variance for the whole mn items is

$$V_{\text{whole}} = \Sigma u^2 - \frac{(\Sigma u)^2}{nm} \quad \ldots\ldots\ldots\ldots [1]$$

This is the first of the relationships we shall need. Next consider the variance of the means as measured from the grand mean. This would be

$$V_{\text{means}} = \text{Sum of (Column means)}^2 - \frac{\text{Sum of column means}^2}{\text{Number of columns}}$$

Since means of the columns are $\Sigma x/n$, and so on, we have

$$V_{\text{means}} = \left(\frac{\Sigma x}{n}\right)^2 + \left(\frac{\Sigma y}{n}\right)^2 + \left(\frac{\Sigma z}{n}\right)^2 + \left(\frac{\Sigma w}{n}\right)^2 - \frac{1}{m}\left[\frac{\Sigma x}{n} + \frac{\Sigma y}{n} + \frac{\Sigma z}{n} + \frac{\Sigma w}{n}\right]^2$$

$$= \frac{1}{n}\left\{\frac{(\Sigma x)^2 + (\Sigma y)^2 + (\Sigma z)^2 + (\Sigma w)^2}{n} - \frac{(\Sigma u)^2}{nm}\right\}$$

[4] "Laboratory Handbook of Statistical Methods," by Brown, Bingham, and Temnomeroff, McGraw-Hill Book Company, Inc., 1931.

This is the second of the formulas. The third is the variance inside the means. This is represented by the sum of the variances found within each column. It therefore equals the variance within the first column plus the variance within the second, and so on. Hence

$$V_{\text{within columns}} = \Sigma x^2 - \frac{(\Sigma x)^2}{n} + \Sigma y^2 - \frac{(\Sigma y)^2}{n} + \Sigma z^2 - \frac{(\Sigma z)^2}{n} + \Sigma w^2 - \frac{(\Sigma w)^2}{n}$$

$$= \left[\Sigma x^2 + \Sigma y^2 + \Sigma z^2 + \Sigma w^2\right] - \frac{(\Sigma x)^2 + (\Sigma y)^2 + (\Sigma z)^2 + (\Sigma w)^2}{n}$$

by rearranging terms.

The first term equals Σu^2. If we add and subtract $(\Sigma u)^2/nm$ we will get

$$V_{\text{within columns}} = \Sigma u^2 - \frac{(\Sigma u)^2}{nm} - \frac{(\Sigma x)^2 + (\Sigma y)^2 + (\Sigma z)^2 + (\Sigma w)^2}{n} + \frac{(\Sigma u)^2}{nm}$$

$$= V_{\text{whole}} - V_{\text{means}}$$

Hence it is necessary to calculate for this case only two variances, since the third may be obtained by subtraction.

The application of theory to the data is given in Table 3.

TABLE 3 MOST PROGRESSIVE RADIO MANUFACTURERS

	North-east	Mid-West	South	West	Sum	Sum of squares
Manufacturer 1....	155	365	206	263	989	268,855
Manufacturer 2....	198	223	140	152	713	131,637
Manufacturer 3....	89	209	119	191	608	102,244
Others.....	11	29	10	8	58	1,126
No choice.....	67	45	27	58	197	10,607
Total.....	520	871	502	672	2,565	
Sum of squares....	75,760	229,501	77,026	132,182		514,469

$$\text{Correction term} = \frac{(2565)^2}{20} = \frac{6,579,225}{20} = 328,961.2$$

$$V_{\text{whole}} = 514,469 - 328,961 = 185,508$$

$$V_{\text{means of geographic districts}} = \frac{(520)^2 + (871)^2 + (502)^2 + (672)^2}{5} - 328,961$$

$$= \frac{1,732,629}{5} - 328,961$$

$$= 346,526 - 328,961 = 17,565$$

$$V_{\text{means of manufacturers}} = \frac{(989)^2 + (713)^2 + (608)^2 + (58)^2 + (197)^2}{4} - 328,961$$

$$= \frac{1,898,327}{4} - 328,961$$

$$= 474,582 - 328,961 = 145,621$$

$$V_{\text{within columns and rows}} = 185,508 - 17,565 - 145,621 = 22,322$$

	Variance	Degrees of freedom	Mean variance
Means of districts.....	17,565	3	5,855
Means of manufacturers....	145,621	4	36,405
Remainder.....	22,322	12	1,860
Total.....	185,508	19	....

The next step is to determine whether the ratios between the mean variances are significant. For this purpose we use in each of the two comparisons the mean variance of the remainder 1860. This number corresponds to a value representing the experimental error which frequently is found in engineering data. It represents the variation or changes between numbers in the table which cannot be accounted for definitely either as changes between districts or changes between manufacturers.

The interpretation is to be found in comparing each of the other two mean variances with this "remainder." It would seem reasonable that such a comparison might be expressed in the form of a ratio which would be equivalent to the difference between two logarithms. Tables of the differences of the two logarithms have been compiled by R. A. Fisher. One of Fisher's tables[3] is calculated on the basis of one per cent probability that the observed variations could occur by chance. The other table is on a 5 per cent basis. We interpret one per cent probability as one chance out of 100 that the variations observed in the table of data result from the way in which the sample happened to be selected. The 5 per cent table indicates a similar statement for a condition of five chances out of 100. The values taken from the tables depend in each case on the number of degrees of freedom used in calculating the mean variances both for the "remainder" and the quantity to be tested.

For the table which we are considering the calculations are as follows:

$$\log 5855 = 3.76753$$
$$\log 1860 = 3.26951$$
$$0.49802$$

Since Fisher's tables are based on the natural system of logarithms times the factor $1/2$ instead of the common system, this number must be multiplied by 1.15129.

$$1.15129 \times 0.49802 = 0.57337$$
$$n_1 = 3, \qquad n_2 = 12$$
$$1 \text{ per cent} = 0.8919$$
$$5 \text{ per cent} = 0.6250$$
$$z = 0.57337$$

From this it is seen that one chance out of 100 that this variation could occur by accident is 0.8919, that five chances out of 100 is 0.6250. The actual value is slightly less than this. We conclude that the chance this may have occurred by accident is more than five out of 100. Consequently, we are not sure of the significance of the differences obsereed as between geographic districts.

The ratio between 36,405 and 1860 is so large that no further test of its significance is necessary.

On the basis of the results we conclude that the table as given consists of an overextended classification. All effective material could be obtained from the table through a condensation of all of the figures into a single column. A further conclusion is that the market as far as this particular factor is concerned does not vary from one section of the country to the other. It therefore must be considered as a unit and consequently for this factor a single standard is sufficient.

(*Continued on page 764*)

The Technique of MARKETING RESEARCH

By GEORGE W. KELSEY[1]

DURING the past forty years, extensively since 1911, industry has adopted the principles and mechanisms of scientific management. Budgetary control, production planning, time and micromotion study, standard costs, and other techniques have become part and parcel of the factory executive's daily program. Meanwhile a gradual evolution has taken place in the distribution of goods, stimulated by the obvious necessity of moving the products of mass production. However, only to a limited extent has industry adopted a technique for the solution of its marketing problems that is consistent with its application of science to products and production.

We hear a great deal these days about overproduction and overmechanization. While there has been overexpansion and misapplication of industrial and agricultural effort in a few instances (created by the abnormality of the World War period) the major problem is that of inadequate distribution or underconsumption. Every one has less than he would like to have of those things which add to the comfort and joy of living. Thousands have only the bare necessities of life.

MARKETING RESEARCH A FACT-FINDING PROCEDURE

Sending the office boy to the library to obtain certain statistics, mailing a few hundred questionnaires to customers and prospects and tabulating the returns, the exhibition of a model to a few individuals for comment, and like haphazard procedures do not constitute marketing research.

The scientific approach to problems of distribution has not progressed to the point of setting up a generally accepted terminology. Its analytical aspects, however, have been called "marketing research." Unfortunately, this term has been used to mean almost anything.

Marketing research is a fact-finding procedure in the realm of distribution, a technical operation intended to provide those in executive authority with necessary factual information.

Adequate marketing research involves:

(1) A study of administrative and executive policies as they affect marketing operations or results.

(2) A study of the product from the standpoint of the ultimate purchaser, to determine utility, satisfaction value, optimum price, style, and quality.

(3) A study of the market, to determine its accessibility, extent, location, and disposition.

(4) A study of the channels of distribution, to determine trade practises, dealer attitude, and the like.

(5) A study of methods and means, i.e., selling and advertising technique, service, the use of premiums, samples, and demonstrators.

All of these considerations form an important part of a genuine marketing research. If one aspect is slighted, misleading—often damaging—conclusions may result.

RESEARCH PROCEDURE

In making studies of this character we follow the same fundamental procedure as when undertaking product and methods research, to wit:

(1) It is necessary to have a clear understanding of the problems to be solved. What we wish to learn must be noted and discussed by all interested parties so as to avoid any possibility of misunderstanding.

(2) It is necessary to prepare plans that will govern procedure during the investigation. At this point we must discover the sources of information; learn how the information can be most readily obtained; instruct those who are to participate; prepare literature and forms.

(3) It is necessary to obtain the evidence. This may involve a review of all pertinent literature and/or laboratory analyses and tests, as well as contact in the field with those who buy, sell, or use the product under consideration. The purpose is to obtain every fact, opinion, experience, or prejudice that may possibly help in solving the problem.

(4) It is necessary to correlate results. The data gleaned from all sources must be accumulated, correlated, tabulated, and often retabulated, until all significant facts have been brought to light.

(5) It is necessary to present the conclusions, in report form, properly summarized and illustrated.

To illustrate modern marketing-research technique, let me outline briefly the procedure followed in one case.

An industrial concern of moderate size was considering the manufacture and distribution of a new product—a mechanical device for use in the home. This was comparatively inexpensive to make and products of its type enjoy a wide market. The product was well suited to the manufacturing facilities of the company but there was reasonable doubt as to whether it could be distributed by the existing organization. Two working samples had been made. The tools for production represented a substantial investment.

The problem in this instance involved a consideration of all factors bearing on the distribution of a single product. Specifically, (1) should this company undertake the manufacture and distribution of this particular product and, (2) if so, how should they proceed.

At the start our attention was directed to the product itself and to a comparative study of all similar devices we were able to locate on the market.

By laboratory and practical application tests, during which we studied the outstanding features of every article with which this company's product must compete, we established *tentative* criteria of quality, weighing the importance of each feature. These criteria represented the characteristics of an *ideal* product, that is, one incorporating the best features of all the products studied. At the same time we prepared a list of questions to be used in a field survey. The field survey was planned with

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care and in detail, yet many of the details had to be revised as we proceeded to interview potential purchasers of the product. Those interviewed were divided into groups or classes so that later on we could tell which group or class contained our best prospects.

By this survey we determined how much educational work had been done by other manufacturers; who did or would use a device of this sort, and why; what price was being paid or would be paid; how the device would be used by those who did not take the time to read instructions carefully; how and where it would be kept by the user; the general reaction to the product as designed by our manufacturer, etc.

The field survey was continued until a current tabulation of results showed that we were getting fairly uniform averages.

The next step consisted of a field study of trade practises for a product of this type, that is, discounts, publicity, dealer helps, general advertising and, of chief importance, the attitude of the trade.

With the results of laboratory and field studies analyzed and tabulated we had the necessary information at hand to formulate an intelligent answer to our first question, Would it be advisable for this company to undertake the manufacture and distribution of this product? That question was answered in the affirmative.

From then on our attention was directed to designing the article and its package for appearance appeal at the point of sale and in use, and to the formulation of a sales structure and program.

Sales arguments and preferred selling price could be readily determined from the wealth of material at hand. We had definite information concerning what the consumer wanted, what would interest him, and the channels that would reach him most effectively. It was decided to distribute the product direct to retail stores in large cities, using special salesmen who would operate under the already existing sales manager. Furthermore, from our survey of the trade we had useful information on what would be necessary to assist the retailer in obtaining a satisfactory volume of sales.

With much of the guesswork and gamble eliminated, the necessary appropriation was forthcoming, production was started and sales were obtained in a satisfactory volume.

MAINTENANCE

By a stretch of the imagination this procedure may be likened to the erection of a building, in that all plans are made and the specifications for each member are carefully set before actual construction begins. As a building when completed needs constant maintenance, so likewise, but in a different sense, the marketing structure must be maintained. It must be checked from time to time. In selling merchandise we deal with human beings, and many influences may occur to alter the facts as they exist at the time of our study. Frequently important changes occur within a period of two years.

In the example cited, one man who worked closely with us and was familiar with our procedure and findings, was delegated by the management to check periodically certain of the more important conclusions.

RESEARCH PERSONNEL

Many companies make what I believe to be a serious error in expecting capable salesmen to keep them posted on consumer and trade facts that are to be used as a basis for determining policy and procedure in selling their products. A good research man approaches his work as one who does not know but who is intensely interested in finding out—one with an inquiring mind. A good salesman, on the other hand, knows his product and is enthusiastic about it. Unconsciously he tends to implant his convictions in the minds of those he interviews. He is inclined to accredit their approval and to discount their objections.

Whether the individuals who are engaged in marketing research are regularly employed by the company for which the study is made, are attached to the staff of an outside organization, or are employed by an advertising agency is of little importance. The important thing is that the study be capably planned and executed, sufficiently extensive, and wisely interpreted.

SOME EXAMPLES

As it is logical to expect, a genuine marketing research often reveals that a project should not be undertaken or should be discontinued. Negative findings of this type are often valuable.

Consider the case of a company that had been recently formed and modestly financed for the manufacture and distribution of a new product. As a first step in our fact-finding program, the ultimate purpose of which was to develop a sales plan and organization, we made a preliminary consumer survey. With this background we were able to view the product from the standpoint of the ultimate user as we proceeded with a series of laboratory tests, comparing this product with every similar product we could find on the market. This article happened to be a special cleaning preparation that had to meet rather extensive competition.

By a series of laboratory and practical application tests it became evident in time that the product of our manufacture was one of the best. However, this product was no better, in our opinion, than ordinary water. That seemed incredible, and every effort was made to find an application where it would be equally effective and easier to use or more effective than water when following the prescribed method of application. The inventor of this product had provided with his preparation a unique method of application and it turned out that the procedure and applicator were the significant elements, not the cleaning preparation itself.

The public is gullible and almost any product can be sold if it is cleverly promoted and extensively advertised. However, the intrinsic merit of a product will, in the long run, prove the determining factor in its success or failure. Then there is, of course, the matter of good business ethics. We recommended in this case that the product be dropped, and it was. While the losses assumed up to that point, were not pleasing to contemplate, they were, however, a drop in the bucket compared to what the loss would have been if the program had been carried out and then proved a failure.

Let me offer one more example, principally because it is somewhat at variance with the common conception of marketing-research activities. As I have mentioned, studies of this character are usually undertaken to determine what can be done to improve the sales of an existing product or what should be done in order to introduce a new product effectively.

In this case we were engaged by a distributing concern to select products that represent best value from the standpoint of the ultimate consumer; specifically, for example, that of selecting best value in a home coffee maker.

First, we obtained necessary background information from literature on the subject and by consulting with specialists in the food field. We learned, for instance, that the quality of a finished cup of coffee as it appears on the dining-room table depends upon five factors: (1) The character of the original coffee, (2) the freshness of the roasted coffee, (3) the freshness

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Some Aspects of QUALITY CONTROL

By W. A. SHEWHART[1]

NEEDLESS to say, the problem of controlling quality is not the same for all kinds of product or for all kinds of conditions. For example, it may be one thing for a large producer and quite another for a small one; one thing for a product of short life and another for a product of long life; one thing for a product that has been produced in much the same way for ages and quite another for a new kind of product. What I have to say is directly applicable to a large producer who assumes the responsibility of providing his consumers with a product of a standard of quality which is satisfactory, adequate, dependable, and economic from a long-range viewpoint and of changing this standard whenever the developments in the field of applied science make such changes desirable. It is felt, however, that most of the points to be made have significance in any control program.

The object of this paper is to make clear what is meant by quality in a practical objective way that is subject to experimental verification and to consider some aspects of the problem of control. As a basis for judging the quality of current product it is necessary to obtain first of all adequate information, in the most efficient manner, on which to render a judgment. This can be accomplished by providing an inspection specification which is distinct from the design specification. One specifies the quantity and kind of evidence that is required as a basis for judging whether or not the quality of the product will attain its goal, the other specifies the goal. Certain elements of uncertainty must be allowed for in setting the goal. The discussion closes by pointing out the necessity of keeping a running report or record of the evidence used in judging the quality of current product as a part of any scientific plan of making use of hindsight as well as foresight in controlling quality.

Before we can talk intelligently about control of quality, we must make clear what we mean by quality in a practical, objective way that is subject to experimental verification. The object of this paper is to provide such a meaning and to consider some aspects of the problem of control. It will be shown that quality has objective meaning only in an operational, statistical sense, and that the statement that the quality of a given thing is such and such is a probable inference which has definite meaning only when (1) the such and such is specified in an operationally verifiable way, and (2) when we know the evidence upon which the inference is based. It will be shown that to specify quality in this experimentally objective way involves three steps: (*a*) Specification of qualia to be experienced, (*b*) specification of an experimental operation, and (*c*) specification of a technique of verification. Such a set of specifications for a quality characteristic constitutes a quality mark, as it were. However, as will be shown, the problem of control does not become definite from an experimental viewpoint until the degree of assurance of hitting this mark is also specified. The specification of the quality mark and of the desired degree of assurance consitutes a definite quality goal and is a legislative function. In the same sense the production of things designed to attain the quality goal and the judging of the things thus made as to whether or not available evidence gives adequate assurance that they will attain the goal are coordinate functions. As a basis for judging quality of current product it is necessary to obtain first of all adequate information upon which to render a judgment. Furthermore, it is desirable to get this information in the most efficient manner. These objectives can be met by providing an inspection specification which is distinct from the design specification. One specifies the quantity and kind of evidence that is required as a basis for judging whether or not the quality of current product will attain its goal, and the other specifies the goal. The judgment of quality upon the basis of such evidence is a step which must allow for certain elements of uncertainty in the setting of the goal.

Our discussion closes by pointing out the necessity of keeping a running report or record of the evidence used in judging the quality of current product as a part of any scientific plan of making use of hindsight as well as foresight in controlling quality.

MEANING OF QUALITY

We want a practical, verifiable meaning of quality. Why not look in the dictionary, you say; but it will do no good for we shall not find one there. Let me give one such illustration: Viz., quality comes from "qualis" meaning how constituted and signifies what a thing really is. This dictionary definition like all others that I have seen certainly does not fill the bill. For example, today as never before we realize that we do not know what makes a thing what it really is. How then could one verify such a concept of quality? How could one control that which he does not know? If one talked in this meaningless way, he would not be likely to make much progress in developing a rational theory of control.

But we do not need to talk this way. At least since the turn of the century students of science have begun to wake up to the truth in the old adage that "Actions speak louder than words." That is, we are now in a place to realize that practical, verifiable meaning lies in the experience associated with a specific operation. Let us consider in sufficient detail for our present purpose the meaning of quality from this viewpoint.

Our consciousness of the external world at any instant con-

[1] Bell Telephone Laboratories, Inc. New York, N. Y.

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sists of a more or less confused awareness. We soon recognize, however, certain repetitive elements in the stream of consciousness expressible in the form "that looks brown," "looks elliptical," "looks far away." Such "looks" are termed "qualia" and constitute the given in experience. One early recognizes in his stream of consciousness the uniformity of simultaneous appearances of sets of qualia. The next discovery of importance is that such uniformities are usually, if not always, followed by other recognizable sets of qualia, provided we act in a specified manner. Thus one comes to interpret the consciousness of such a set of associated qualia as a signal of the possibility of experiencing a definite previously conceived succession of associated qualia. The objectivity of experience consists in the verifiability of this succession as predicted. Such an objective succession of associated qualia constitutes the quality of a thing or object. *It follows that the concept of quality of a thing has the meaning of a succession of perceivable qualia associated with a previously conceived or specified set of operations.* Conclusions of far-reaching importance follow from this concept of quality, as we shall now see.

First, it is significant that there is not a universal meaning to the quality of a thing because objective thinghood lies in the possibility of experiencing a previously defined set of qualia associated with a previously conceived set of operations, the number of possible such sets of operations being indefinitely large. We have no rational basis for talking about *the* quality of a thing except in reference to a specified set of operations. For example, my concept of the quality of an automobile is fixed by the qualia which I expect to experience when operating a car as I do. Both in that we may not have interest in the same sets of qualia and in that we do not operate cars alike, there are grounds for marked differences among our individual concepts, although they may be expected to have definite similarities. Moreover, the concept of the consumer or user of anything, such as an automobile, usually begins with the finished product, whereas the concept of the producer begins with raw material and includes all operational steps in development, design, and fabrication, as well as a specified operation of the finished product.

Second, it is significant to note the nature of the verifiability of an external object or thing, such as any piece of manufactured product, in terms of a concept of quality. As noted, such a concept held by any individual involves a succession of qualia experienceable as the result of previously specified sets of acts or operations. If the sets of specified operations involve a finite sequence of sets of qualia, the individual may be said to have verified the object or thing thus conceived when, upon carrying out the operations, he has observed the sequence of qualia within the limits of error of his perception.

Third, it is significant to note that up to the time the producer delivers the finished product to the consumer, he can have verified any specified concept of quality only up to the time of delivery. In delivering the product to the consumer, he can only *judge*, with a probability less than certainty, that the consumer's concept of quality will be verified. In other words, it is not humanly possible for the producer to render other than a probable judgment as a basis for which he must rely on the following generally accepted postulate of probable inference: *The objective degree of rational belief p'_b in an inference or judgment P is not an intrinsic property like truth but inheres in the inference or judgment through some relation to evidence Q.* There follows from this postulate the important fact that the degree of rational belief in the judgment that the concept of quality of a given piece of product, involving operations after it leaves the producer, will be found to be verifiable, depends upon the set of previously observed sequences of qualia taken as evidence.

Perhaps a schematic diagram will help to fix the essential elements in the meaning of the quality of a thing. The judgment that the quality of a thing is such and such is essentially a prediction of the future. For such a prediction to have definite and verifiable meaning at any time taken as the present, it must be in terms of one or more sets of qualia to be experience-

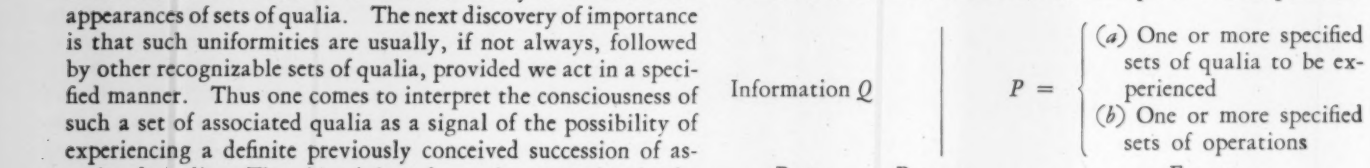

FIG. 1

able respectively as the result of one or more definitely specified operations. The degree of rational belief p'_b in the prediction depends upon the information Q which we have about the thing up to the present. Since, as just stated, the degree of rational belief p'_b in a judgment P inheres in this judgment through some relation to evidence Q, it is evident that the judgment that the quality of a thing will meet the conditions P is meaningless as a probable inference unless we know the evidence Q. Likewise the judgment is meaningless in any sense that can be verified experimentally unless the sets of qualia and associated operations are definitely specified.

We are now in a position to consider in turn the meaning of three types of quality of interest from the viewpoint of control.

QUALITY OF TYPE 1

Definition: Quality of Type 1 is that which characterizes a thing itself independent of all other things and of human volition and interest.

Non-critical common sense attributes to every thing or object about us certain quality characteristics independent of human interest. Fundamentally, such quality characteristics are supposed to represent the objectivity of the external world, or the given in experience, or that part of experience which comes to us whether we wish it or not when we act in certain ways; they are supposed to represent what is knowable about the real external world; for the most part at least they are the type of characteristics in which the engineer conceives of the quality of a piece of apparatus as being that which makes it what it is and which he tries to include in his specification of the physical aspect of that piece of apparatus; they are the characteristics that the hard-boiled, cold-blooded natural scientist attributes to the external world in which we live, as usually contrasted with the wish-colored and interest-tinged quality characteristics of experience in which we try to interpret the whole of experience or, more particularly, our likes and dislikes and our method of valuing external objects.

In so far as these common-sense quality characteristics may be observed either in the form of the pointer readings of the physicist and chemist such, for example, as those interpreted as mass, density, resistance, capacity, and velocity, or in the form of direct sensations, such as color, they become experimentally verifiable and have objective meaning.

Strictly speaking, the quality of any object is relative, although as engineers we are perhaps justified in considering some quality characteristics, as, for example, mass, as being independent of other things, as well as of human interest and volition. There are, however, many quality characteristics such as linear dimensions, volume, density, resistance, and the like, which are fixed in terms of operations so long as such operations are carried out under the same essential conditions.

Fundamentally, there is always implicitly involved in the concept of the objectivity of the quality of an object the assumption that the conditions under which this quality is to be measured or experienced are to remain *essentially the same*. That is to say, scientific method never gets away from depending upon the human element involved in judging conditions to be the same except in so far as the type of observer can be specified as a part of the operational technique. The meaning of quality of Type 1 is partially fixed by the operations involved in the measurement of such quality, including those taken to insure that the same essential conditions are maintained.

As a result of a series of n repetitive operations or measurements of some property such as mass, we get n observed values $m_1, m_2, \ldots, m_n$ which, in general, will not be the same even though conceptually the mass of the real object under the same essential conditions is assumed to be a constant m'. That is to say, even though there be a *real* mass which is constant when the real essential conditions are kept constant, such mass is not experienceable except in the form of measurements involving definite operations, and the results of such successive operations are not constant but constitute an observed frequency distribution.

Now, let us consider what it means to verify a quality characteristic of Type 1 that can be observed again and again under presumably the same essential conditions, because, as we have noted, the objectivity of quality must lie in the experienceability of a certain predetermined set of qualia associated with a given set of operations. As an example, I am thinking of the thickness of a particular type of feeler gage. According to the design specification, this gage is to have a uniform thickness of 0.008 in. ± 0.0003 in. The specification goes on to define the procedure or operation of measurement and to describe the same essential conditions so as to be intelligible to an experienced operator. Can such a quality characteristic be verified? To make the problem more specific let us assume that you are a consumer in the market for a gage as thus specified, and that I am a producer of such gages. Assume that I have one of my gages here in my hand and that I tell you that it has the quality specified. What would constitute a verification of my statement?

The answer to this question is that there is not a definite process set forth in the specification by which to make a verification. For example, you might measure the gage according to the procedure specified and get an observed thickness of 0.0083 in. If you take four more readings you may, however, get values such as 0.0084, 0.0082, 0.0084, and 0.0083 in. According to the first, third, and fifth readings, the gage is within the specified range. Two readings are outside and the average of the five is outside the limits. Obviously, for the quality characteristics to be verifiable it is not sufficient to state the method of measurement and to maintain the same essential conditions in so far as possible. It is also necessary to specify the number of measurements to be made the basis of the verification as well as the method of using these measurements or, in other words, a statement as to whether the limits 0.008 in. ± 0.0003 in. apply to each of some specified number n of observations or to some function of these such as an average. Only then does the quality of thickness become objective and experimentally verifiable.

In general, to make a quality specification objectively verifiable it is necessary that it specify: (*a*) The qualia to be experienced, (*b*) the accompanying operation, and (*c*) the detailed technique of verification. Thus in the case of the gage, the quale is the scale number, the operation is the method of manipulating the gage and the measuring mechanism, and the verification is defined in terms of an operation on a specified finite number of scale readings. Likewise in shooting at a standard target with a rifle, the quale might be the scale reading representing the distance from the edge of the hole made in the target to the center of the target, the operation would include specifications as to the manner of shooting at the target and of measuring the quale, and the method of verification would, as before, define an operation involving a finite number of scale readings.

Thus far we have considered a quality characteristic that can be measured again and again under presumably the same essential conditions. Of course there are many characteristics for which the operation of measurement is destructive so that verification must be in terms of a single observation.

We are now in a position to consider some important aspects of the problem of judging quality of Type 1, illustrated schematically in Fig. 2, for any quality characteristic X of a given thing.

A set-up such as sketched in Fig. 2 holds for each quality characteristic used to determine or specify the quality of a given thing. As already noted, the judgment that the quality of a thing will meet the specification P_X is a probable inference derivable in a rational way from evidence of the type Q_X. It is of interest at this point to note that in the case of a probable inference about a quality characteristic of Type 1, such as thickness, where repetitive measurements on the same thing can be made at will, all of Q_X can be made the grounds of the inference, whereas in the case of a quality characteristic in which the measuring operation is destructive, only parts *b*, *c*, and *d* can be used as grounds for such inference.

From the viewpoint of control of the quality characteristic X of a given kind of thing, the set of specifications P_X constitutes

$$Q_X = \left\{ \begin{array}{l} (a)\ \text{Measurements of } X \text{ on given thing} \\ (b)\ \text{Measurements of } X \text{ on things of the same kind made in the past under presumably the same conditions} \\ (c)\ \text{Evidence that measurements made under presumably the same essential conditions give no indication of the presence of assignable causes} \\ (d)\ \text{Other relevant information such as measurements of other quality characteristics on the given thing; past experience with similar things; and consistency of measurements on a given thing with all prior accepted facts that are pertinent} \end{array} \right| \quad P_X = \left\{ \begin{array}{l} (a)\ \text{Specified qualia to be experienced} \\ (b)\ \text{Specified operation} \\ (c)\ \text{Specified technique of verification} \end{array} \right.$$

Past Present Future

FIG. 2

the target usually set up before commercial production starts. Of course, the specifications P_X cannot be set out of thin air. Instead they must represent a practical mark which means that they must take into account manufacturing limitations. As a result, the specifications for the quality of a new kind of product are ordinarily taken as tentative and may be changed after a

study of the results of early production. The important point for the present discussion is simply that before any one particular piece of product is produced there is some set of specifications P_X serving as a mark for that piece. The production organization aims at this target in producing things of the given kind. However, before any piece of product is actually fired at the target, it is necessary, in accord with the policy we are here considering, that sufficient grounds of the type Q_X be available and that those give adequate assurance that the piece of product will hit its quality mark. It is the function of what I shall term the inspection specification to fix the operation of choosing the necessary amount of information of type Q_X in the most economical way.

In general, it should be noted that the specifications P_X serving as a mark for a given piece of product must take place before production of that piece and constitute the quality mark of production, whereas the inspection specification, in so far as it uses (as it is almost sure to do) evidence of Types *a* and/or *b* and *c* of Q_X in defining a definite inspection operation must be in terms of data accumulated after the goal is set and production started. Furthermore, we need to keep in mind that the inspection specification is definitely different from the specified technique of verification under P_X, a fact that is generally overlooked. For example, P_X defines something wanted or, in other words, an end to be attained, whereas the inspection specification defines an operational step constituting one of the means to this end. The means may change though the end remains fixed, as I shall now illustrate.

Let us assume that n measurements of X are required on this thing to give the necessary assurance that it will hit its quality goal. Now, suppose that, after having made, let us say, 1000 things of this kind, on each of which we have made n measurements, we make the observation that the one thousand appear to have come from a statistically controlled product. The assurance given by the n measurements, let us say on the one thousandth one, taken with the fact that there is no evidence of lack of statistical control, is greater in general than the corresponding assurance given by the n measurements on the first one. If only n were required on the first, less than n are required on the one thousandth one to give the same assurance. In other words, the number of measurements per piece required to give the necessary assurance depends upon the history of the degree of control of the production process and cannot be specified once and for all in the same way that the aimed-at quality can be specified.

In fact, it turns out in general that the minimum amount of sampling required to give adequate assurance of quality of product is attained when the quality gives evidence of being controlled in the statistical sense. Hence in order to reduce to a minimum the cost of inspection effort required to give adequate assurance, it is desirable to take into account evidence of the existence of control, which can be done, of course, only as the production process gets under way.

Thus far we have considered the quality of a thing itself in so far as it is possible to free it from the influence of all other things in a practical engineering sense. We must next consider the quality of a thing in relation to the quality of other things.

QUALITY OF TYPE 2

Definition: Quality of Type 2 is that which characterizes a thing A in its relation to another thing B as a part of a whole and independent of human volition and interest.

This is the sense in which one speaks of a piece part in its relation to the whole of which it is a part or in the sense that parts of a telephone circuit, for example, contribute to the transmission characteristics of the circuit. Other typical examples are the quality of one condenser as a part of the overall quality of two condensers in series or parallel; the qualities of resistances, inductances, and capacities as parts of the overall impedance of a circuit; the quality of a conduit to resist corrosion; the quality of a chemical compound as a plant fertilizer; and the quality of a drug as a medicine. The quality of a thing in this relational or use sense may be extended indefinitely at will.

For our present purpose, let us consider the meaning of quality of Type 2 that has significance from the viewpoint of the control of quality. To begin with, let us consider any piece of equipment or apparatus built up of a number N of different kinds of parts as, for example, an automobile, electric fan, telephone instrument, or the like. Let us assume that the quality of the whole W in which we are interested is expressible in terms of m_2 quality characteristics $Y_1, Y_2, \ldots, Y_i, \ldots, Y_{m_2}$, each having operational meaning. From the viewpoint of controlling the quality of any piece part A, we, of course, try to determine the set of m_1 quality characteristics $X_1, X_2, \ldots, X_i, \ldots, X_{m_1}$ of the part A itself, the control of which is a necessary and sufficient condition for controlling the contribution of the part A to the quality of the whole W, expressed in terms of the m_2 quality characteristics of the whole. Let us assume, moreover, that the desired quality of the whole can be given objective, verifiable, operational meaning by m_2 sets of operations of the form P_{Y_i}, where P_{Y_i} has for the quality characteristic Y_i of the whole the same significance as P_X (Fig. 2) for the quality characteristic X of the part. Ideally we try to set up for any part A the m_1 sets of operations of the form P_{X_i} which are to be met if the part A is to contribute as desired to the quality of the whole when the same conditions are satisfied for each of the N piece parts constituting the whole.

There are at least three distinct ways in which a quality of a part may contribute to the quality of the whole. First, there is the case where the quality characteristic of the whole in which we are interested has the same operational meaning as the quality characteristic of a part A, and where these are mathematically related through past experience. An example is the quality characteristic of capacity of a condenser considered in its relation to the capacity of two or more condensers in series or parallel. Second, there is the case where the quality characteristic of the whole in which we are interested does not have the same operational meaning as the quality characteristics of its parts, although these are mathematically related through past experience. An example is the impedance of a circuit in terms of the resistances, capacities, and inductances of elements of the circuit. Third, there is the case where the quality of the whole does not have the same operational meaning as the qualities of the parts and where they are not mathematically related through past experience. Examples of this case are the qualities of a chemical compound as a fertilizer, the quality of a drug as a medicine, the quality of sheet metal to resist corrosion, and the contribution of piece parts in an automobile to such a quality characteristic of the whole as its smoothness of operation.

The problem of controlling the quality P_{Y_i} ($i = 1, 2, \ldots, m_2$) of the whole through the control of the quality P_{X_i} ($i = 1, 2, \ldots, m_1$) of a part is fraught with many more difficulties and more uncertainties in the third case cited in the previous paragraph than in either of the other two. In particular, it is extremely difficult to determine a set of necessary and sufficient conditions P_{X_i} ($i = 1, 2, \ldots, m_1$) for a part in terms of conditions P_{Y_i} ($i = 1, 2, \ldots, m_2$) in the case of a chemical, drug, or sheet metal, as a fertilizer, medicine, or resistance to corrosion, respectively, because it is difficult to attain precision in carrying on experiments under the same essential conditions.

Now, the important point to which I wish to call attention is that in going from the specifications of the form P_{X_i} for a quality characteristic X_i of a part to its contribution to the quality of a whole, there is an element of uncertainty. In other words, we can never be sure that $X_1, X_2, \ldots, X_{m_1}$ constitute the necessary and sufficient set of quality characteristics that should be controlled so as to control the quality contribution of the part to the whole. Hence the judgment of quality of product involves two elements, viz., (*a*) judging the quality of current product as to whether or not the available evidence of the form Q_X is such as to give adequate assurance that the quality will hit its mark, and (*b*) judging when the failure of the quality to hit its mark is attributable to lack of control of the proper quality characteristics of the parts. The attempt to hit a quality mark of the form P_{Y_i} $(i = 1, 2, \ldots, m_2)$ for the whole through the control of the quality characteristics of the parts reminds one of the gunner shooting at an object he cannot see by aiming at the specifications set for him as to elevation, correction of wind velocity, and the like. In both cases, as elsewhere in life, it is not only how we aim but how we hit that counts, so that the specification defining the aim must be changed when a sufficient number of hits are not made. The gunner must rely upon some one to analyze the placement of shots and tell him whether or not there is evidence of assignable and uncontrolled causes or variation, much as the one who draws up the specifications of the form P_{X_i} must rely upon the judge of quality to tell him when the deviations in the m_2 quality characteristics of the whole from their specified values P_{Y_i} are greater than must be left to chance and hence indicate that the specifications of the form P_{X_i} $(i = 1, 2, \ldots, m_1)$ for the part are not sufficient.

QUALITY OF TYPE 3

Definition: Quality of Type 3 is that which makes a thing wantable by some one or more persons.

Thus far we have considered the meaning of the quality of a thing as independent of human interest or volition. Fundamentally, however, the ultimate goal of the producer under conditions which we are here considering is to produce a product the quality of which will be adequate, satisfactory, and dependable to the consuming group. This makes it necessary to consider the wantableness of a thing as the ultimate goal at which the producer is aiming in the control of quality of a product.

From the viewpoint of control, one of the first steps to be taken is to determine in what sense quality of Type 3 has an operationally verifiable meaning, realizing that the consumer is primarily interested in the operational characteristics of the finished thing in the sense, for example, that I as the user of an automobile am primarily interested in the operation of that automobile and not so much in the quality of Types 1 and 2 of the piece parts. For our present purpose let us assume that there is some set of m_3 quality characteristics $Z'_1, Z'_2, \ldots, Z'_1, \ldots, Z'_{m_3}$ of the finished thing such that when these take on any set of fixed values, the degree of wantableness of the thing is fixed. Stated in another way, let us assume that two things which are alike within specified limits in respect to these m_3 characteristics are equally wantable, and in turn that the degree of wantableness is fixed by variations in this set of characteristics for this particular kind of thing. The goal of the producer is, of course, to produce a thing of the given kind having the particular set of values of these m_3 characteristics which will harmonize and maximize the satisfaction of this kind of thing for the consuming group.

Now, let us assume that there is some set of specifications of the form $P'z'_i$ $(i = 1, 2, \ldots, m_3)$ such that they define in a definite, operationally verifiable way the desired quality characteristics of a thing from the viewpoint of the consumer. From a producer's viewpoint in respect to a given kind of thing, such a set of specifications characterizes the ideal of quality that will give maximum satisfaction. If we were in a position to specify the operational characteristics of a thing in this ideal way, there would be no difference between what I have called the specifications P_{Y_i} $(i = 1, 2, \ldots, m_2)$ and the specifications $P'z'_i$ $(i = 1, 2, \ldots, m_3)$. In much this same manner we are in a position to view what may be considered the ideal goal in quality control, namely, the setting up of a set of specifications of the type P_{X_i} $(i = 1, 2, \ldots, m_1)$ for each piece part such that if they are met for each part and the parts assembled at random, the finished article will be the ideal desired. In actual production, of course, we have to deal with the judgment that a given piece part will meet its specification and hence it would be necessary in the ideal situation for us to be in a position to note with certainty for each part that it would later prove to have the desired quality.

Perhaps the most important point to note about this ideal quality goal is that there are two distinct elements in it: (*a*) The specifications $P'z'_i$ $(i = 1, 2, \ldots, m_3)$ which would make the meaning of quality definite and experimentally verifiable, and (*b*) the ideal requirement that we be able to judge with certainty whether or not a piece of product at a given time is such as will meet the specified ideal requirements. In other words, it is not sufficient to be able to specify the mark that we are supposed to hit in this ideal situation; in addition we must also know when the thing is such that it will hit that mark.

Now, let us look at the practical situation. Sometimes wants are well enough defined in terms of verifiable operational quality characteristics to enable us to set up what is pretty close to the ideal quality mark, as in the case of the establishment of the desired operational characteristics of some circuit. In turn it may be feasible through accumulated experience to provide a circuit which we believe with a high degree of rational belief will meet the requirements in respect to the operational characteristics. In general, however, it is not possible to set down in operationally verifiable form the requirements $P'z'_i$ $(i = 1, 2, \ldots, m_3)$. For example, such a specification for milk written a few years ago would not have included any requirements as to operations to insure against tubercle bacilli or to give assurance that the milk would contain the necessary vitamins by requiring that the cows be bathed with the proper amount of sunshine or fed the proper amount of spinach. Who knows what such an attempted specification will look like at some future date? Much the same situation is true when we try to provide a set of specifications of the form $P'z'$ for any one of the hundreds of different articles which we use every day.

In other words, there is always an element of uncertainty that any set of operationally verifiable specifications P_{Y_i} $(i = 1, 2, \ldots, m_2)$ constitute the ideal set. Hence in considering the problem of control of quality from a practical viewpoint, we must take into consideration the degree of uncertainty involved in assuming that the set P_{Y_i} $(i = 1, 2, \ldots, m_2)$ is the ideal set $P'z'_i$ $(i = 1, 2, \ldots, m_3)$. Furthermore, we must take into account the fact that we cannot with certainty establish a set of operationally verifiable requirements of the form P_{X_i} $(i = 1, 2, \ldots, m_1)$ for a part that are necessary and sufficient to control its contribution to the quality of the whole. In turn, there is always the element of uncertainty in any prediction about the experienceable quality of a part based upon information of the form Q_{X_i} $(i = 1, 2, \ldots m_1)$ about that part.

In the practical problem of control, there may be more steps

than those which I have indicated in the sense that partial assemblies of piece parts are often thought of as wholes which in turn become piece parts for larger wholes. Thus, in the telephone plant there are something like 110,000 different piece parts, groups of which are assembled to constitute different kinds of parts which in turn are assembled into still larger parts and these ultimately into the completed telephone system. Likewise in an automobile, there are the piece parts which go together to make up the carbureter; other piece parts which go to make up the engine; other piece parts to make up the body, etc. Fundamentally, however, there are only the two kinds of quality characteristics of a thing, whether it be a piece part or something made up of several piece parts, in that there is the quality of a thing by itself and the quality of the thing taken in relation to something else. Hence for our present purpose, it is not necessary for us to complicate the picture by introducing more steps than we have. We should, however, point out the obvious fact that in the control of quality of anything considered as a whole, it is customary to apply, in those cases where possible, certain measuring operations to the whole which are to be taken together with the information of the type Qx of each piece part as a basis for judging the quality of the whole, and, in turn, similar operations may be performed on partial assemblies.

There are, of course, three more or less fundamental aspects to the problem of control. One is that of setting up the specifications of the form P_{X_i} $(i = 1, 2, \ldots, m_1)$ on the part and of the form P_{Y_i} $(i = 1, 2, \ldots, m_2)$ on the whole in the specific sense in which we have defined them in this discussion. To make this goal objectively complete, however, it is also necessary to specify the degree of belief or assurance that a piece part, partial assembly, or assembled whole will meet its respective set of specifications. To do this economically, it is desirable, of course, to take account of the fact that we can never be certain of any step and hence that the requirement as to the degree of assurance that a piece part should meet its specification is somewhat dependent upon the degree of assurance that the whole will meet its specified quality when the piece parts meet theirs.

In other words, we have the steps of going from Qx to P_X, from P_X to P_Y, and from P_Y to $P'z'$. If it were possible to express our degree of belief as a commensurable probability, we could say that the probability of taking the first step is p'_{b1}, the second step p'_{b2}, the third step p'_{b3}. It would follow that upon the evidence Qx the probability of hitting the final mark would be the product of these, namely, $p'_{b1}p'_{b2}p'_{b3}$. Hence in trying to determine the economic advantage of increasing one of these probabilities by a certain fixed amount, we must note that the final increase will be less than this fixed amount. For example, if we increase the first probability by an increment $\Delta p'_{b1}$, the overall increase in assurance will be only $p'_{b2}p'_{b3}\Delta p'_{b1}$.

JUDGMENT OF QUALITY

While this first step is legislative in character, the second step is that of producing or manufacturing physical things designed to meet these specifications. The first step is largely one of specification or legislation; the second is one of execution. The final step is that of judging whether or not an actual piece part or whole when produced is likely to meet its specifications and whether or not there is any evidence that the specification should be changed. I have discussed elsewhere some of the aspects of the theory of control in economic production. I wish now in closing to emphasize some aspects of the problem of judging the quality of product.

As we have already seen, the judgment of quality has objective, operationally verifiable meaning only on condition that we have, for the part or for the whole, specifications of the form P_{X_i} $(i = 1, 2, \ldots, m_1)$ or P_{Y_i} $(i = 1, 2, \ldots, m_2)$, respectively, and also that we have some definite indication of the degree of assurance that we are to have in rendering the judgment that the quality of a particular piece part or whole will meet its associated specification. To a large extent, the fixing of these specifications and the desired degrees of belief is a legislative function which is tempered in practise by a knowledge of the economic attainableness of any specified goal. We have seen, moreover, that there must be an element of uncertainty in the fixing of such specifications. It follows, therefore, that the problem of judging quality of product is not alone to see for each accepted piece of product that there is available evidence to give adequate assurance that it will hit its quality mark, but also to see that any failures to hit this mark are analyzed in such a way as to indicate whether or not it is desirable to modify the specifications.

If the quality goal is specified in a definite manner, the first problem in judging the quality of product is to determine in a given case *how much* information of the type Qx should be collected and *how* this information should be selected from the classes a, b, c, d, under Qx of Fig. 2 in order to be most economical. For example, such questions are involved as: How many observations shall be made on an object when tested? How are we to depend upon evidence of statistical control in the quality of product of a like kind? How much shall we depend upon other pertinent information?

In practise, however, it is very often the case that the specifications are incomplete in one way or another. In particular, they often fail to specify in an objective operational manner the verifiability of the quality desired and likewise often fail to indicate explicitly the degree of assurance that one should have in judging that a piece of product will meet its quality mark. In such a case, the first step in the judgment of quality involves the interpretation of specifications in a way to make them complete.

Another fundamental step in judging the quality of product is the interpretation of the evidence thus accumulated to determine whether or not it gives adequate assurance that the piece of product will meet its quality mark. In making such interpretation, due allowance must be given for the fact that practical quality specifications of the form P_{X_i} $(i = 1, 2, \ldots, m_1)$ or P_{Y_i} $(i = 1, 2, \ldots, m_2)$ have in them an element of uncertainty, so that cases may arise where the resultant effect of non-conformance of a piece of product in respect to one quality characteristic may be in a given case counterbalanced by the effect of the non-conformance of another in the opposite direction.

In the judgment of the quality of the final product, it is desirable to keep a running record of the evidence made the basis of the decision that the current product going to the consumer will meet its quality mark P_{Y_i} $(i = 1, 2, \ldots m_2)$. Such a record, in so far as it reveals evidence of statistical control of quality characteristics up to a certain time, constitutes a basis for reducing to a minimum the amount of inspection that is required to give adequate assurance that current product will be found to have the quality specified. Such a record also constitutes a scientific basis for the adjudication of complaints and helps to make it possible to determine in a given case whether or not a complaint condition is attributable to an assignable variation from the specified quality, P_{Y_i} $(i = 1, 2, \ldots, m_2)$, and to trace evidence of the presence of assignable causes of deviation from such specified quality back either to the lack of control of specified qualities of the piece parts or to the insufficiency of the specified quality characteristics of the parts.

The OPERATION *of a* SUGGESTION SYSTEM

The Development and Characteristics of the Suggestion System at the Kodak Park Plant of the Eastman Kodak Company

By VIRGIL M. PALMER[1]

THIS paper briefly describes the purpose of a suggestion system as installed and operated in the Kodak Park plant of the Eastman Kodak Company at Rochester, N. Y. It will sketch the plant conditions to which it was applied, outline the present system and show changes which have been made in the original plan in developing this system, and appraise the actual results accomplished.

PURPOSE OF THE SUGGESTION SYSTEM

The announcement of March, 1898, launching the suggestion system read as follows:

In order to stimulate the hearty cooperation of our employees at Kodak Park and increase their interest in matters pertaining to the successful operation of the plant, we have decided to offer six prizes for the best suggestions made by employees. These prizes will be awarded every month and all employees are free to compete for them with the exception of superintendents of departments. All foremen are eligible. These suggestions may relate to improvements in product, method of manufacture, systems employed, and to the general management of the factory. Anything, no matter how small, that will be an improvement, will come under this head. A suggestion to wash windows where it may be needed, or to pick up rubbish, will be as welcome as some suggestion relating to important improvement in processes. All suggestions will be welcome, and we wish every one to feel that his or her ideas are wanted on any subject where improvement may be possible.

The prizes, which will be awarded every month for the best suggestions, will be

One prize of $20
One prize of $10
Four prizes of $5 each.

In distributing these prizes, only those suggestions will be considered that are actually *put into execution* or *are adopted*. This is necessary because employees might make suggestions which, for various reasons were impracticable, and which would be of no real value to the company. When suggestions are received, all that are practicable and that can be adopted will be put into execution, and all of those so adopted will be considered in awarding the above prizes.

Detailed instructions followed as to obtaining suggestion blanks, how they should be filled out, and the location of boxes into which they should be deposited.

This announcement was issued by the plant manager. The response was so great and enthusiastic, that for April the prizes were increased to one prize of $20, one prize of $10, six prizes of $5 each, and six prizes of $2.50 each. In addition, a yearly prize of $100 was offered for the most valuable suggestion received up to January 1, 1899.

The first "Suggestion Bulletin," that of May 9, 1898, was written as a personal letter from Mr. Eastman to all Kodak Park employees. This showed that 162 suggestions had been made, of which 94 (57 per cent) were adopted, 62 were "not adopted," and 6 were held under consideration.

FIG. 1 SUGGESTION BOX

(Note suggestion poster, suggestion-disposition bulletin (*a*), suggestion-deposit slot (*b*), and supply of suggestion blanks (*c*).)

The suggestion system got away with a splendid start, as it had the benefit and prestige of the management's personal interest. It was regarded as an important mechanism of management. This attitude has remained unchanged over the years.

Another important psychological advantage that has contributed largely to the success of the system is the management's attitude of appreciation of any and all suggestions for improvement, with never a criticism of former conditions which the suggestions seek to improve. I know of no surer way to secure bitter foremen resistance to a suggestion system than for the management to criticize the conditions disclosed through suggestions as needing improvement.

Then, too, from the outset, the system has had the advantage of good publicity through the "Suggestion Bulletin," through the employees' magazine, and through posters on the suggestion boxes, bulletin boards, etc.

PLANT CONDITIONS TO WHICH THE SYSTEM IS APPLIED

Kodak Park, in reality, is not a single plant, but is an aggregation of plants, each making its own product. These products vary widely as to physical and chemical

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properties, equipment used, production operations, and quantities made. There are, for example, departments making chemicals needed in subsequent operations, such as nitric and sulphuric acid. More than 60 per cent of the occupations recognized by the United States Census Bureau, as well as many peculiar to the plant, are followed.

All departments are tied together through common management and through centralized service units, such, for example, as the engineering and maintenance department, which provides power, heat, light, refrigeration, compressed air, maintenance, etc. The different departments are under the supervision of department superintendents, grouped under general superintendents, who report to top management. Such is the plant to which the suggestion system is fitted.

In some departments methods and equipment are fairly stable and standard, while in others methods and equipment are in a condition of flux, with rapid development and change. In some departments operations are involved and intricate and require extensive experience and technical control. In others the work is comparatively orthodox and regular.

In some departments slight improvements multiplied by the number of occurrences mount to important savings. In others, important improvements, because of small volume, amount to a small total. Slight improvements in highly developed, usual, and customary practise, may reflect much greater effort and initiative than important improvements in new or changing processes not yet settled down to approved routine.

PRESENT SUGGESTION SYSTEM

The present system has evolved through experience and plant growth, from the original. Briefly, it is as follows:

The suggestion system is set up as a responsibility of the personnel department with a suggestion secretary reporting to the plant employment manager. With 7300 employees, the work takes the full time of a combined stenographer and filing clerk and three-fourths of the secretary's time, the remainder of which is spent in other personnel effort, such as managing the employees' athletic activities. The secretary is thus in a favored position to maintain close contact with all employees and to get and hold their confidence.

The suggestion secretary aids suggesters, as necessary, to give better expression to their ideas and helps them with their suggestions. He gives out the suggestion-award checks, or orders on the pay-roll department for cash, for adopted suggestions, and explains personally, when this is necessary, the reasons for rejecting suggestions. He follows up suggestions referred to the department superintendents for consideration, acts as secretary to the suggestion-award committee and prepares and issues the "Suggestion Bulletin." His work will be described in more detail later.

SUGGESTION-AWARD COMMITTEE

The suggestion-award committee consists of five department superintendents, the suggestion secretary, and the employment manager, ex officio. The present committee consists of superintendents of the engineering and maintenance department, the paper mill, the film-emulsion coating department, the chemical plant, and the department of industrial economy. The membership of the committee is changed from time to time, thus ultimately giving all department heads personal experience and insight into the problems and accomplishments of the system.

It is the responsibility of the committee, subject to the manager's approval, to consider and pass upon all suggestion awards, i.e., to see that they are reasonably uniform, just, and fair, both to the employee and to the company. The purpose of a suggestion system is to arouse and to stimulate cooperation, initiative, and interest of the employee in the job, and to provide for a free flow of ideas from the rank and file to management. The measure of success is the employee's psychological reaction to the system. Prompt determination of just and fair awards is most important in obtaining proper reaction from the employees. The suggestion-award committee interviews department superintendents and other supervision, as necessary, for information in arriving at the value of suggestions adopted, or for the reasons for rejection of suggestions.

ELIGIBILITY FOR AWARDS

Employees below the rank of assistant superintendent, with a few exceptions, are eligible for suggestion awards. These exceptions are certain restrictions on some employees of the engineering and maintenance department, the industrial-economy department, and the research laboratory, whose responsibility it is to produce and develop new ideas, and whose rates are set accordingly. The restrictions apply only to suggestions on activities coming within the line of duty of the employee. Suggestions may be submitted and awards are made on ideas which fall definitely outside such duties. For most jobs, written job analyses and specifications exist and these are valuable in determining the "line of duty" of the employee.

ROUTINE OF THE PRESENT SYSTEM

To make the suggestion system plain, we shall follow its operation. An employee wishing to submit a suggestion, goes to one of the 65 boxes located at prominent points about the plant and gets a blank. The suggestion box (see Fig. 1) is really a combined bulletin board, suggestion-blank dispenser, and receptacle for suggestions. Old home-made boxes were displaced by these new, attractive ones some years ago, when they were found available and when additional ones were needed because of increased plant size. They are part of a ready-made suggestion system, which is commercially available.

Suggestions may be submitted either signed or unsigned. Both receive equal consideration, the only difference being that the identity of the maker of anonymous suggestions remains unknown, except to the suggestion secretary, to whom the suggesters come with their stubs for identification and for their award, after notice of adoption of their suggestions has been posted on the bulletin boards.

Suggestions are collected from the boxes every other day. They are dated as received and those signed are promptly acknowledged.

The percentage of signed and unsigned suggestions is a rough indication of the employees' confidence in the suggestion system. Eighty-one per cent of the suggestions received in 1933 were signed, and 88 per cent of those adopted were signed. Of the unsigned ones, a high percentage are of a trivial nature. The suggesters of these appear not to wish their names known, despite the company's attitude indicated at the beginning of this paper.

The follow-up file card and the employee's name card, upon which is recorded all the suggestions made by that individual, are next made out. The employee's name card gives an accumulative record of all suggestions made. These cards are consulted by the supervisory staff in connection with transfers or promotion of employees, or in filling some position which requires unusual keenness, alertness of observation, initiative, and ingenuity.

The suggestions are next checked by the suggestion secretary to see that they are complete and understandable. This

includes an interview with the suggester and trips to the departments and executives involved, when necessary. Triplicate copies of the suggestion are then made and sent to the superintendent of the department to which the suggestion applies. The original suggestion is filed alphabetically according to the superintendent to whom it is referred.

Suggestions are considered by the superintendent, the assistant superintendent, or by an assistant to whom this work is delegated and who is responsible for fair, prompt, and sympathetic handling of suggestions. Formerly, suggestions were referred to department foremen, but there was a wide difference in the attitude of these men toward suggestions, and it was difficult to follow them up and get prompt action. The change to the present method has resulted in better and quicker handling, in closer contact between the supervision, the employee, and the suggestion secretary, and in greater confidence and interest.

CONSIDERATION OF SUGGESTIONS

Suggestions apply to a wide range of subjects. One suggestion was that stuffed owls be put in the ivy covering many of the buildings to keep the sparrows out; another, that an outside hatch be made to facilitate getting heavy grinding wheels into and out of a basement; a third, that refrigeration be discontinued as unnecessary in the conditioning of some of the products. The first suggestion was rejected; the second was awarded $25; and the third received an award of $1500.

For uniform classification and award, Table 1 is used.

TABLE 1 CLASSIFICATIONS AND MINIMUM AWARDS

Class 1	Improvement in product	$10.00
Class 2	Reduction in costs	7.50
Class 3	Improvement in manufacturing methods	5.00
Class 4	Reduction in accident or fire hazard	2.00
Class 5	Convenience	1.00

A careful investigation is made to determine the purpose or objective of the suggestion; what changes, if any, must be made to put it into effect; what the cost of its adoption will presumably be; and the saving per year or other value to the company. The conclusions from this investigation are indicated on the triplicate form, "superintendent's copy of suggestion," one copy of which is returned to the suggestion secretary as the superintendent's report, the other two copies being retained by the department. If the superintendent recommends the adoption of the suggestion, this report also gives the recommended award, and, if the suggestion can be made immediately effective, the date on which it was put into operation is indicated.

If the suggestion is adopted, but cannot be made effective until later, the award is made and the suggestion secretary follows up the suggestion, sees that it is put into operation and that the date on which it was actually in operation is recorded on the blank at this time.

If the suggestion is not adopted, specific reasons for its rejection, with a supplemental statement, if necessary, must be made. Suggesters whose signed suggestions have been rejected, are so notified. The reasons for rejection of the suggestion are explained in this notice. The numbers of unsigned rejected suggestions are listed on a suggestions-disposition bulletin, which is posted on all suggestion-box bulletin boards (see (*a*) Fig. 1).

Suggesters are encouraged to communicate with the suggestion secretary, if they do not thoroughly understand the reasons for, and concur in, the rejection. Such contact broadens the point of view and understanding of these employees, who have shown initiative and have been sufficiently interested in their work and in the company to make suggestions. Not infrequently, such discussion brings out good ideas which make the suggestion worth while and justify an award, but which were concealed or were not made evident because of the inadequate way in which the suggester expressed himself in writing out his suggestion. This contact also often provides a vent for pent-up feeling, usually the result of lack of understanding or peculiar individual emotional characteristics.

Every two weeks the suggestion secretary prepares a list, "suggestions recommended for adoption." These suggestions are listed under the superintendent to whom they have been referred. The classification, rating, and recommended award are shown for each suggestion. The suggestion-award committee considers these lists and approves or disapproves the adoption of the suggestions, the classification, and the awards recommended. The committee can and does change the recommendations for awards, if this seems advisable. Such action, however, is never taken without full discussion with the superintendent or his delegated representative. When necessary, the suggester is called in to be sure that his suggestion is fully understood. This handling has been very successful in getting cooperation from, and the confidence of, the rank and file of employees.

AWARDS

Monthly competitions, with cash prizes for the best suggestions, were splendidly successful in launching the suggestion system. Competitions make good publicity and stir up interest and enthusiasm. With a system well established, however, the competitive feature is less important. With the growth of the plant, it became advisable not to limit the awards to a prescribed number, but to make them available to all through paying for all suggestions adopted and put into effect. Cash prizes were therefore soon discontinued and were replaced with awards for all adopted suggestions.

There are two kinds of awards, i.e., "regular" awards, and "additional" awards. The regular award is the original one recommended by the superintendent and passed on by the award committee. The value of the suggestion, when the regular award is made, is estimated, but is not demonstrated by actual experience. The tendency, therefore, is to play safe and recommend a conservative amount. Care must be exercised not to overdo this. As Seneca said, "He who gives timely, gives twice." A good award given promptly, while the suggester's interest and enthusiasm are keen and fresh, is worth many times the amount given as an additional award several months later when interest has dulled and enthusiasm is gone.

Twice a year, in April and in October, all suggestions which were made effective during the first and last six months, respectively, of the preceding year are reviewed. At this time there is actual operating experience of from 9 to 15 months from which to judge the value of the suggestion. If this value is greater than the amount on which the regular award was based, an additional reward is paid, so that the total will be just and fair.

AMOUNT OF AWARD

The amount of the award approximates, roughly, 10 per cent of the first year's savings when this can be estimated or is finally known. It is less for large amounts, especially if derived from comparatively slight unit savings multiplied by large mass production. It is more when derived from important improvements in quality of product or processing methods. The ingenuity, initiative, perseverance, and resourcefulness of the suggester are taken into account in deter-

mining the amount. Awards for a single suggestion have run as high as $1500 and $2000.

Over the years, attempts have been made to set up some formula for a more rigid basis of award evaluation, but without success. This is not surprising when all of the widely varying conditions are considered. After all, however, if awards are roughly fair and just, extreme precision is not necessary. Their purpose is to get proper employee reaction in the form of "hearty cooperation . . . and interest in matters pertaining to the successful operation of the plant." This is a psychological reaction, to which precision of measurement is as yet inapplicable. The award committee plan has resulted in greater uniformity in appraising suggestion values and fairness in determining just awards.

PAYMENT OF AWARD

Following each award committee meeting, the list of adopted suggestions with approved awards is submitted to the plant manager for authorization. This then becomes the treasurer's authorization for payment.

DISPOSITION OF SUGGESTIONS

The disposition of a suggestion is recorded on a suggestion disposition form, which is posted on the bulletin section of the suggestion boxes. This is notice to the suggesters of adopted suggestions to call for their awards.

For uniformity, when the system was changed in 1929 and the choice of signing or not signing suggestions was provided for, this somewhat cold and impersonal method of notifying suggesters of the disposition of their suggestions was adopted. There has been no noticeable effect upon the attitude of the employees.

MONTHLY "SUGGESTION BULLETIN"

The "Suggestion Bulletin" is issued twice a year and is distributed to all employees. This bulletin lists the accomplishment of the system for the period. It gives the total suggestions adopted and the total amount of the awards, both regular and additional. It lists the employees receiving awards, describes the adopted suggestions, and gives the amounts of the awards.

All employees, whose yearly total of suggestion awards received is $25 or more, are listed in an "honor roll," which is posted on the bulletin boards all over the plant.

Stimulating and inspiring suggestion posters are purchased from a service agency and different ones are posted weekly on the poster section of the suggestion boxes. These posters frequently outline problems or activities in which suggestions are desired. For example, reduction of waste, elimination of red tape, etc.

This completes the description of the system routine.

CHANGES IN THE SYSTEM

The important changes in the system have been as follows:

Awards are now given for all adopted suggestions, instead of offering prizes on a competitive basis, as formerly.

Foreman Made Eligible for Awards. For a period, foremen were made ineligible for awards, because of what appeared to be a suspicion on the part of employees that foremen rejected suggestions, only to use them later and get credit for them. To compensate for this, and to stimulate the foremen to encourage their employees, awards were given to the foreman having the highest ratio of adopted suggestions to labor force. However, because of the variations in product and departmental conditions, this ratio did not reflect relative accomplishment. The foreman of a small department making a new product, with methods in the process of evolution, would have a prolific field for suggestions and would rank the highest, whereas a foreman in a large department, with stabilized methods, might have worked much harder to get his employees to make suggestions and have nothing to show for it. For this reason, and for the further reason that, with foremen ineligible, the type of suggestions received fell off, foremen were reinstated and again made eligible for awards. This change was not made, however, until after a suggestion-complaint committee had been organized and had functioned for a long time. The committee reported directly to the manager, and in secret session heard all complaints of unfairness or misappropriation of suggestion credits. Actually, the committee had practically no cases to investigate, but the psychological effect was splendid and such lack of confidence as had existed (and I believe this was overestimated), was restored. Foremen have been continuously eligible for suggestion awards since.

Determination of Awards. Originally, awards were determined by the plant manager, with such assistance as he might need from the then few superintendents. With plant growth this developed into a superintendents' suggestion meeting, consisting of all department superintendents and key staff executives. These meetings were presided over by the plant manager. The meetings were double-purpose affairs, at which both plant matters and problems of common interest were discussed, as well as suggestions and suggestion awards.

(NOTE: Now, suggestions which have common application to two or more departments are called to the attention of the department heads through a letter, either from the suggestion-award committee, or from the plant manager, if the suggestion is of general interest or of sufficient importance.)

Suggestion awards of less than $10, if unquestioned, were approved without discussion. Awards amounting to more than $10 were discussed individually by the entire group. The purpose of the general discussion was to insure plant-wide application of the suggestions, where applicable; to get uniformity of award recommendations; and to keep the management's interest and desire for suggestions constantly before the entire official family.

With further plant growth, the committee became too large and unwieldly. There was lack of common knowledge of the operations to which suggestions applied and hence, of their value. The system was then changed and the present suggestion-award committee plan was put into effect. This, with some changes in personnel, has functioned since.

Certificate of Merit. For a period of five years, employees attaining the suggestion honor roll were sent a certificate of merit, signed by the manager. When the supply of blanks was exhausted, this practise was discontinued without any apparent reaction on the part of the employees.

Names of Suggesters. When the suggestion system was started, suggesters sent in their suggestions signed, but for some time these names were not included on the copies sent to the superintendent for consideration. Later, when the management felt sure that fair and impartial consideration would be given to suggestions, the names were added, as the lack of the suggesters' names hampered proper investigation.

However, it was found necessary to provide a means for anonymous suggestions. The unsigned suggestion provides a safeguard against opposition from a foreman or other members of the supervision. It provides the timid employee with a means of presenting his ideas, and occasionally an outstanding one is obtained, which otherwise would not have been submitted.

Suggestion-System Secretary. The suggestion system was first the responsibility of the manager's office, and then of the assistant manager's office, after which a combined suggestion-system secretary and safety engineer was appointed. These two jobs were subsequently divided and the system routine has been the responsibility of the secretary ever since. At first, he reported to the assistant manager. This procedure was later changed to the present plan under which the secretary reports to the manager through the employment manager, as previously stated.

RESULTS ACCOMPLISHED

From the beginning, the system has been considered important and not a side issue. The benefits derived from it are proof of the truism "You get out of a thing just what you put in."

The bulletin of April, 1899, contained the following:

WHAT TO SUGGEST

In making suggestions, the real purpose of the suggestion system should be kept in mind. Repairs should not be made the subject of suggestions unless a new method of making repairs is proposed. Where repairs are needed, ordinary supplies wanted, or tools need to be replaced, the foreman of the department should be notified and the matter not made the subject of a suggestion. Whatever will effect an improvement in machinery, methods, or processes of manufacture, or cause a saving of time, labor, or material, is a proper subject for suggestions. The purpose of the suggestion should be to effect improvements over the past or existing conditions.

I shall cite two examples of suggestions resulting from posting problems upon which suggestions were desired:

In the early period of this industry, when amateur roll film had been on the market but a short time, an easy way for the user to break the band that encircled the roll was badly needed. This customers' convenience would facilitate the use of the film and would reduce sales resistance. The problem was baffling. Mr. Eastman asked for suggestions and a simple answer was promptly forthcoming, for which an award of $500 was given. The suggester afterward became general foreman of the film-finishing department.

Recently, an automatic machine which had been purchased outside left a burr from a sawing operation. The manufacturer's designers and our own engineers found no remedy. The department operating the machine asked for suggestions, and the machine "fixer" suggested a simple improvement by which motion was taken from a reciprocating machine element to actuate a knife blade which neatly sheared off the burr.

Departments which post problems and suggestions wanted, show their employees by this action that they are in accord with the system, and they stand out prominently, because of the resulting high percentage of suggestions received, total savings effected, and awards given.

As stated previously employee-suggestion record cards are frequently consulted when department heads are seeking men for jobs requiring initiative, original thinking, and ingenuity. In checking through some early lists of suggesters, the author was astonished at the number who subsequently became important department heads. Out of fourteen prize winners in the first "Bulletin," two became department superintendents and three became general foremen. Approximately 40 per cent of those whose names appear on subsequent "Bulletins" eventually became foremen, general foremen, or superintendents. The percentage is high, and this is probably due to the fact that our business was of a pioneer type with rapid growth, and also to the fact that there was then a dearth of technically trained men. With further growth, evolution, and standardization of methods, subdivision of operations, specialization, and technical control, such percentage, of course, was not maintained.

A check-up of the tangible results for the period 1922 to 1932 showed the following:

Average number of suggestions received per 1000 employees	235
Average number of suggestions adopted per 1000 employees	83
Percentage of suggestions received which were adopted	35.4
Average suggestion award, including additional awards	$7.30
Average number per year of additional awards paid	25.8
Average total of awards paid	$4,011.00
Average total of estimated savings	$31,175.84
Average ratio of yearly savings to awards paid	7.8

This is a splendid return when it is remembered that while some savings do not repeat and some suggested changes would have been made anyway in the regular course of business, still others do repeat for many years.

There is a wide fluctuation in the record for different years which it is difficult or impossible to explain. Much of this is due, however, to outstanding suggestions which cannot be expected to repeat with any regularity. Some yearly differences reflect varying employee interest in the system. Suggestion systems, like everything else, do not run themselves, but must be continually "pepped" up.

To insure general and active participation in the system, we have found it necessary to acknowledge promptly all suggestions; to give open-minded, receptive consideration to all suggestions; to make quick decision with fair and adequate awards for those adopted and explanation of the reasons for the rejection of those not adopted; and to give publicity, through the "Suggestion Bulletin," to important suggestions which carry large awards as a stimulus, not only to the suggesters concerned, but to all employees.

Design of BOLTED FLANGED CONNECTIONS

By E. O. WATERS,[1] D. B. WESSTROM,[2] and FRANK S. G. WILLIAMS[3]

UNTIL recently there has been no uniformity of practise on the subject of designing bolted flanged connections. The formulas for the stresses involved have been known, but it remained for a joint committee composed of members of The American Society of Mechanical Engineers and the American Petroleum Institute to bring the entire subject into a usable form. The results of this work appeared in the May, 1934, issue of Mechanical Engineering, pages 311–313. The rules for design recommended by this joint committee were adopted and are now part of the A.S.M.E. Code for Unfired Pressure Vessels and the A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels for Petroleum Liquids and Gases.

For the benefit of the engineers who use these codes, the authors of this paper are commenting on the important phases of flange design with the hope that they may cast light on some of the reasons that lie behind various sections of the rules. It is the authors' wish not only to clarify but to offer suggestions that will be helpful to the designer on the points where judgment rests on him alone. References made in the text to figures and code paragraphs are to the 1934 revisions of the A.S.M.E. Code for Unfired Pressure Vessels and the new A.P.I.-A.S.M.E. Code for Petroleum Liquids and Gases in this order. Furthermore, the nomenclature used in this paper corresponds to that used in the codes.

In Bulletin B—16e the American Standards Association has developed dimensions for flanges of all standard pipe sizes up to 24 in. diameter, inclusive, and for various pressures up to 1500 lb per sq in. at 750 F, and corresponding higher or lower pressures at other temperatures. The rules under discussion strongly recommend the use of these standard A.S.A. designs wherever possible. They have proved their safety, and from the viewpoint of economy a standard design will usually be less expensive than a special one. The rules are really intended for use beyond the scope of the A.S.A. standards, but may be used for special cases within the scope of these standards.

There are three separate elements in a bolted flanged connection. We shall consider them in the following order: (1) Gasket design; (2) bolting design; and (3) flange design for (*a*) the ring portion and (*b*) the hub portion of the flange.

A well-designed flanged joint must put sufficient pressure on the gasket to hold the joint tight at all times without overstressing the flange and bolting material. The pressure is applied to the gasket by means of the bolting. The further discussion may be easier to follow if we first examine the conditions that exist in bolted connections under service conditions. When these bolts are initially set up the internal fluid pressure is not present and the total bolt load is available to seat the gasket and insure full bearing and contact over its entire surface. The pressure is then applied and the force compressing the gasket is diminished to a greater or less extent, depending on the relative elasticity of the bolting and the gasket. This residual force required to keep the joint tight is the gasket force (compression).

The unit gasket compression is, of course, expressed in pounds per square inch, and is most commonly designated in terms of a multiple of the internal working pressure of the vessel, which multiple is known as the contact-pressure ratio. In other words, the contact-pressure ratio is the ratio of the unit contact (gasket pressure) to the unit internal pressure. For example, if the unit compression required is 600 lb per sq in. and the working pressure is 100 lb per sq in., the contact-pressure ratio is six.

GASKET DESIGN

The first step is to select the gasket material and its shape. This should be followed by a determination of the flange facing required for use with the gasket. The final step is the selection of the contact-pressure ratio.

Gaskets are of many types so that no attempt will be made to classify them all, but there are a few commonly used types that are easily described. On low-pressure, low-temperature work it is common practise to use a full-face gasket extending to the outside diameter of the flange and with the bolt holes cut out. Such gaskets are usually soft and require a low unit compression to keep them tight. It is rarely that a contact-pressure ratio of more than one or two is required.

Another usual type is a wide ring gasket extending from the inside diameter of the joint to some point within the line of bolts. If this type of gasket were made of a rubber composition or something similar, it would be expected that a small gasket compression would hold the joint tight, but if the gasket material were a hard substance like asbestos composition, a higher unit compression would be required. If such a wide-ring type of gasket were made of hard metal the unit compression would need to be still higher. Such gaskets are usually applied to a flat or raised face on the flange and, generally speaking, their use is limited to 300 lb per sq in. and 750 F.

For higher pressures and temperatures the tongue and groove facings have certain advantages owing to the higher compression on the contact surface which can be secured with reasonable dimensions of bolting. Gaskets for this class of surface vary from widths of $\frac{1}{4}$ in. to 1 in. or greater, and with all kinds of gasket materials. No set rules can be laid down, but in general the designer who chooses a narrow hard gasket must use a much higher unit compression than the one using a wide soft gasket. It has been suggested that a designer can better visualize metal gaskets if he studies the force required to flow the gasket material, for this type of joint depends upon plastic deformation of the gasket for its tightness. It is also

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The authors wish to express their appreciation to the members of the A.S.M.E. Subcommittee of the Boiler Code Committee on Special Designs and to the representatives of the American Petroleum Institute and the A.S.M.E. Sectional Committee B16, for the very considerable assistance which they have given in the preparation of this paper.

recommended that gaskets be as thin as possible to minimize the possibility of their being blown out.

During the years that the American standards for flanged fittings were in course of development there was a common feeling among steam-power engineers that high ratios were necessary to hold joints tight. More recent experience with flanged joints under high-temperature service in central steam stations, and more particularly, experience with heat exchangers and other equipment in oil refineries, would indicate that these ratios are quite conservative. The more recent practise followed by some designers (although by no means universally used) indicates that a lower range of values has been successfully used. These are guide posts only and have no value if not considered along with conditions under which they were successfully used. (See Table 1.)

TABLE 1 CONTACT-PRESSURE RATIOS

	Early practise	Recent practise
Wide raised-face joints	4- 6	2–4
Wide tongue-and-groove joints	8–10	3–6
Narrow tongue-and-groove joints	10–12	3–8

In addition to the types of gaskets already mentioned, there are numerous kinds of metal-to-metal contact joints, the most common of which are the Sarlun joint and the Mid-West joint. The use of these joints is confined largely to sizes 24 in. and smaller within the range of the A.S.A. flange standards. The American standard dimensions have proved their safety when used with these joints, and a designer should have a very unusual need or reason before departing from them.

There is also the connection commonly known as the ring-type joint. This joint has been widely and successfully used. It depends upon a metal-to-metal line contact, so that there is an infinitely high contact-pressure ratio on an infinitely small area. The ring-type joint has been used successfully on high-pressure, high-temperature vessels as well as for pipe connections. It is impractical even to attempt an evaluation of the gasket contact area or unit compression. Perhaps the best analysis of the gasket force required for this joint is a study of the force required to make the metal gasket flow. Another analysis that would permit comparison with other joints would be to assume that the gasket surface had an area determined by the width of the groove at the point where the oval gasket makes contact.

The authors wish to caution all readers that the whole subject of contact pressure is a most elusive one. The foregoing remarks are purely comments on what has been done in the past by various designers, and no one should use this for anything more than a guide because the specific materials handled, the gasket chosen, and the condition of service very largely determine just what the unit compression should be. There is no substitute for experience and judgment. If a designer is in doubt as to the correct ratio to use, it would be wise for him to go back over his past experience and examine designs similar to that of the problem at hand which he knows have been operating safely. He should then check these designs using the schedule of working stresses allowed in the codes, and determine from this what ratios have been successful in the past.

In dealing with the subject of gasket force (compression), it must be realized that there are few or no data from which to work. It was this lack of definite information that accounts for the fact that in Par. UA-19*d*, W-317(4*d*), and R-317(4*d*) the unit compression is not fixed. The designer should also recognize that any discussion of the unit compression cannot be entirely divorced from the consideration of the bolt stresses that are being used in the design. The industry as a whole would be greatly benefited if all designers would keep a careful record of the contact compression ratios that they have used, coupling with this record the details of the type of gasket material, the size of the gasket, the design bolt stress, and the details of the flange facing, etc. If the A.S.M.E. Boiler Code Committee should have such a body of data available two years from now, it is quite possible that more definite and accurate rules could be developed on this particular phase of flange design. The authors make this appeal to all designers, and hope that they will respond by keeping such records and making their experience available.

BOLTING DESIGN

With the size and shape of the gasket established, and the contact-pressure ratio selected, the designer is ready to determine the bolding required. The bolting should be designed to maintain the required compression on the gasket with the internal pressure acting.

The required bolt load W is the sum of:

(*a*) Hydrostatic end force H. Multiply the internal pressure by the area bounded by the outer periphery of the gasket.

(*b*) The gasket force Hg. Multiply the working pressure by the contact-pressure ratio to get the unit gasket force, then multiply this by the annular area of the gasket or compression surface.

It would seem that these two computations are somewhat contradictory in that a comparatively small hydrostatic pressure is assumed to add its effect over the entire contact surface to a much larger gasket pressure. Theoretically, the hydrostatic pressure extends only to the inside diameter of the gasket. However, slight dishing of the flange, minute imperfections in gasket seating, and inequalities in bolt tension all tend to permit the confined fluid to creep over a portion of the contact face. For this reason it is best to err on the safe side and assume the worst possible condition, namely, a hydrostatic pressure extending over the entire gasket face.

The necessary bolt area at the root of the threads is obviously obtained by dividing the bolt load W by the allowable stress. The design working stresses for both carbon- and alloy-steel bolting material are given in the Code. See Par. UA-18 and R-317(3). At this point the designer should sketch a tentative layout showing the desired location and size of gasket or contact surface, hub thickness, and diameter of bolts and bolt circle, and from these set the outside diameter of the flange. In the case of integral flanges, the hub thickness is more or less fixed by the thickness of the neck or vessel of which the flange is a part, although there is the possibility of increasing it above this amount, as by means of a taper (Fig. UA-2*e* and 9*e*). Generally a liberal increase will be found beneficial. For loose flanges, there is no guide except the designer's experience or the A.S.A. dimensions for flanges of comparable diameter and temperature-pressure rating. As a rule past designs have tended to make the hub too thin rather than otherwise.

In working up the sketch, there are several details in connection with bolting which must be considered, as follows:

(1) Small bolts should be avoided wherever possible, owing to the ease with which they may be overstressed by torsion applied with a wrench. Bolts smaller than $\frac{1}{2}$ in. are prohibited by the codes, and if $\frac{1}{2}$-in., $\frac{5}{8}$-in., etc., sizes are used, considerable care should be taken in the make-up of the joints. The ease with which a mechanic with a long wrench, or worse still, a sledge, can twist these smaller sizes as well as stretch them, makes their use relatively unwise except with appropriate precaution.

(2*a*) Bolts should be spaced far enough apart to permit the clearance necessary for socket wrenches, and likewise the

bolt circle on hubbed or integral flanges should have sufficient diameter to permit a generous fillet between the back of the flange and hub.

(*2b*) The Waters-Taylor 1927 A.S.M.E. paper,[4] "The Strength of Pipe Flanges," recommends a bolt spacing of at least $2^1/_4$ bolt diameters between centers to avoid high stress concentration.

(*2c*) On the other extreme the bolts must be spaced close enough to insure a uniform compression on the gasket. A spacing of $3^1/_2$ diameters between centers is probably a reasonable maximum.

(*2d*) Many designers are in favor of, and the A.P.I.-A.S.M.E. Code recommends the use of, bolts of uniform diameter. This is obtained either by through-threading or machining down the bolt over the unthreaded section.

(3) To prevent overstressing of bolted flanged connections, the designer should, wherever possible, set the length of wrench to be used. He should give some cautionary note that wrenches are not to be hammered. If it comes down to a point where the frictional resistance of the nut against the flange face is too great for the ordinary wrench to stress the bolts, an extension to the wrench is much preferable to any form of sledging.

FLANGE DESIGN

The designer having made his choice of gasket material and shape, and determined the bolting required, next turns to the problem of the flange dimensions required to withstand the bolt load with a reasonable stress in the flanges.

The outside diameter of the flange must be large enough to seat the bolt with some manufacturing tolerance to spare. A safe rule to follow is:

Outside diameter of flange = (Bolt circle) + (Width of nut across corners) + $^3/_8$ in.

The $^3/_8$ in. is made up of the following factors:

Oversize of bolt hole, $^1/_8$ in.; outside diameter of flange should be $^1/_8$ in. larger in diameter than the swing of the nuts to allow full seating; manufacturing tolerance, $^1/_8$ in.; a total of $^3/_8$ in.

The next step is to determine the lever arm *a* of the various forces and reactions (see Fig. UA-2 or Fig. 9).

Loose Flanges. (Fig. UA-2*a* or Fig. 9*a*.) For loose flanges the lever arm *a* is simply the radial distance from the bolt-circle diameter to the line of action of the opposing force. In the case of the regular Van Stone joint with a flat back, this line of action is located at the mean diameter of the area of contact between the back of the lap and the face of the flange.

Integral or Rigidly Attached Flanges. (Fig. UA-2*b*, *c*, *d*, *e*, or Fig. 9*b*, *c*, *d*, *e*.) For joints of this type there are three forces to be evaluated, together with their lines of action.

(1) H_D, the hydrostatic end force acting on the area bounded by the internal diameter of the flange or vessel wall, as the case may be, is assumed to act as follows:

(*a*) Integral flanges—acts at the mean diameter of the neck or vessel wall (see cuts *b*, *d*, *e*).

(*b*) Screwed or slip-on flanges—acts at inside diameter of flange (see cut *c*).

(2) H_T, for tongue-and-groove type of facing, is the hydrostatic end force acting on the area bounded by the outside diameter of the gasket and the inside diameter of the flange, and is assumed to act at the mean diameter between outside diameter of gasket and inside diameter of flange or vessel.

H_T, for wide raised-face type, is the hydrostatic end force acting on the gasket surface, and is assumed to act at the mean diameter of the gasket surface.

(3) H_G, the gasket force, whose magnitude has been previously determined, is assumed to act at the mean diameter of the gasket or contact surface.

The points at which H_D and H_G are assumed to act in the formula for *a* are not theoretically exact, but they are far more simple to calculate and are sufficiently accurate for all purposes.

A formula is given in the code for the determination of the composite lever arm to be used in computing the stresses in a flange. It should be noted that neither this formula nor the general rules contemplates the case of a gasket extending outside the bolt circle. The formulas in the code cannot be used for this condition since a different method of calculating the stress is required. This case is in the hands of the committee and a report on the proper handling of this problem will be released in the near future.

At this point the designer has all the information necessary to determine the flange thickness and hub dimensions required in accordance with the formulas given in the codes for this purpose, which are the Taylor-Waters formulas. This is a cut-and-try process in which the designer varies the ring thickness, hub diameter, and hub height until he achieves a combination which gives stresses in the flange and hub within the limits allowed by the codes, with reasonable economy of materials. The first approximation is usually the tentative selection of the ring thickness *t* which can be made by assuming that there is no hub. In this case

$$t = \sqrt{\frac{5.72\ Wa\ X}{BS}}$$

The final thickness is to be something less than this owing to the reinforcing effect of the hub.

The addition of the formula for the critical stress in the hub is a real contribution to flange design. The average designer has been in the habit of determining the stress in the flange itself but has ignored the hub. However, it is well to know that the critical stress in the flange connection may be in the hub and not in the flange. The new code rules recognize this factor in design and should bring about a better balanced construction.

The next step is the determination of the hub dimensions. If the hub is of the integral type, it can be assumed to have either an infinite length or a definite length. Flanges butt welded to shells (Fig. UA-2*e* or Fig. 9*e*) are considered an integral and the shell can be counted as part of the hub in calculating the strength. If an infinite length is assumed, the average hub thickness to be used in the formulas should be taken as the thickness of the vessel or neck wall.

However, in the case of the butt-welded type of flange, it is commercially practical to get a substantial hub thickness immediately beyond the back of the flange over and above the thickness of the vessel wall, and full advantage should be taken of this enlarged hub diameter. In such cases the designer should consider that the hub height *h* (effective hub height) has a value as follows:

$$h = \sqrt{Bg}$$

where B = average diameter of hub of height h
g = average thickness of hub of height h.

Obviously if the hub is partly tapered and partly straight, the average values of B and g will depend somewhat on the value of h, but the difficulty can be overcome by inserting values of B and g in the foregoing formulas on the assumption

(*Continued on page 763*)

[4] MECHANICAL ENGINEERING, vol. 49, 1927, no. 5a, pp. 531–542.

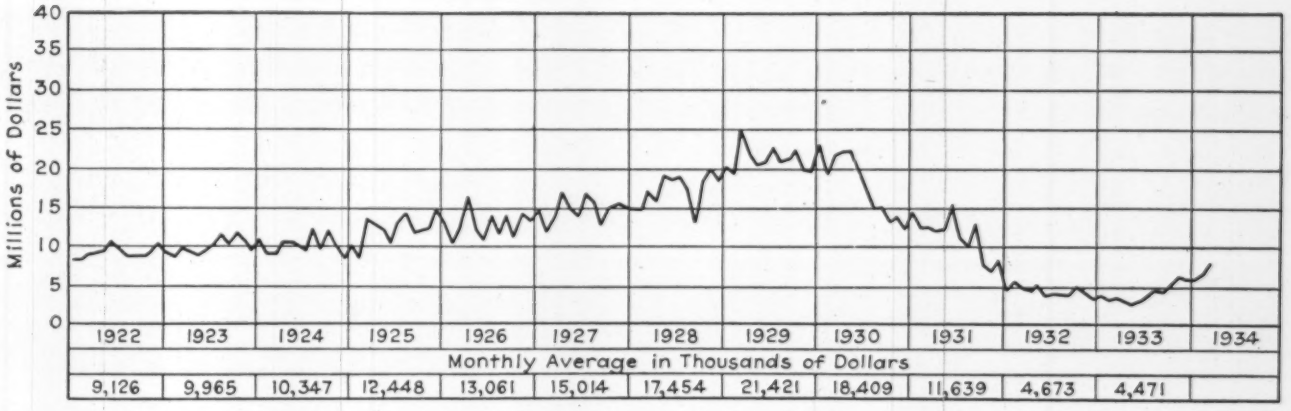

FIG. 1 INDEX OF MACHINE-TOOL ORDERS IN UNITED STATES IN PERCENTAGES OF AVERAGE MONTHLY SHIPMENTS DURING 1926

MACHINE-SHOP PRACTISE

Annual Progress Report of the A.S.M.E. Machine Shop Practise Division for 1934

By R. E. W. HARRISON[1]

A REVIEW of the activities of the past year in industries producing and using machine tools reveals increased evidence of the severity of the depression and the struggle being waged to maintain and advance technological progress, and a tendency in certain uninformed quarters to fix the responsibility for all the social ills of the machine age on the heads of the technicians. The slowing-up in technological progress, due to the depressed state of the durable-goods industries which are the main users of high-grade machine-tool equipment, the shortage in skilled help, which is a direct result of the five years of depression, and the exhaustion of much of the capital and cash resources of the organizations which normally provide the stimulus for industrial development have all combined to impose a severe handicap on an industry which is essentially the keystone of the industrial, social, and economic structure.

Despite this handicap, however, there is progress to be recorded. And despite the fact that in 1933 the machine-tool industry did less than $31,000,000 worth of business, as against the $59,000,000 reported for 1931, it will be noted on reference to Fig. 1 that business is still being sought and obtained, although the volume is such that profitable operation is difficult.

A great deal of constructive thought was brought out by the publication of the *American Machinist's* survey of mechanical equipment in 1930, and the republication of another up-to-date survey in 1935 will go still farther in drawing attention to the desirability of bringing workshop equipment in line with the latest technique and procedure.

The manufacturing technique of the United States developed primarily to meet the needs of an immense domestic market has spread throughout the civilized world, wherever markets have been presented, calling for treatment similar to that which has proved successful on this side of the Atlantic. No more convincing evidence of the penetration of this technique is provided than by the number of American machine tools which are seen in the manufacturing workshops of the world, and reference to Fig. 2 indicates that the upward progress started in the spring of 1933 will be continued. To restore its former position, however, will call for a greatly increased degree of effort in both the domestic and foreign markets and the feeding in of many new ideas.

The controversy brought about by the penetration of the practise of welding in the fields hitherto occupied by cast structures, both steel and iron, has made both necessary and desirable the presentation of both sides of the case in the interests of the designing engineers. This thought was in the minds of the Executive Committee of the A.S.M.E. Machine Shop Practise Division in organizing the symposium on welded vs. cast structures as one feature of the 1934 Annual Meeting.

The introduction of new methods of casting, improved mixtures, and heat treatments giving greater tensile strength, improved machinability, and other properties, together with the introduction into many industries of the practise of automatic welding on a large scale, has complicated the problem and makes the rendering of decisions without all the facts extremely difficult and hazardous.

The thought still grows that the productivity of machine tools can be enhanced by a lightening of the metal-removal burden. Hence, many production engineers are calling for forgings to much closer tolerances, sand-molded castings with the bare minimum of surplus metal, together with die castings and hot-brass pressings, all of which are designed with the object of reducing materially the number and the extent of the machining operations.

In addition to this, the increased use of plastic compounds, as for example, in the manufacture of noiseless gearing, and many other practises formerly considered impracticable because

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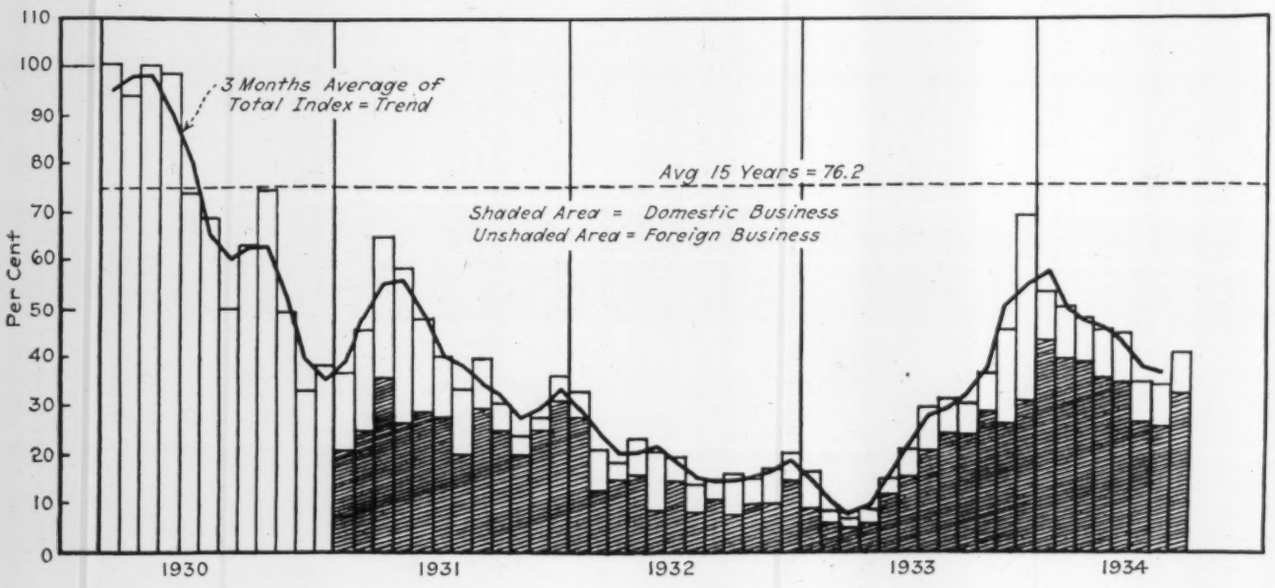


FIG. 2 UNITED STATES EXPORTS OF INDUSTRIAL MACHINERY, BY MONTHS

of limitations in tensile strength are all exerting a marked effect. In many cases the plastic compounds can be molded to finished size without machining, and when parts do require machining the surplus material can be removed in a shorter time than would be the case with a metallic substance.

The phenomenal growth in the practise of surface broaching has resulted in the placing on the market by a number of companies of individual and complete lines of surface-broaching equipment. Almost invariably where these machines have been applied the resulting increase in production and the favorable length of tool life have reduced materially the costs of production. A significant point in design not overlooked by the designers of broaching equipment is the provision of flexibility in the tooling. In each instance the new machines have been provided with the maximum facilities for rapidly changing cutting tools, as well as facilities for the automatic chucking and unchucking of the work.

Much constructive thinking has been stimulated by a number of articles recently published, together with supporting data, indicating that in some instances the use of individual motor drives is accompanied by a higher cost as well as an increase in power required, which goes a long way to offset the value of operating conveniences. This has encouraged the advocates of group drives, with the result that in some instances in the near future we may look to see increased use of the group-drive.

The net result of the controversy is that in the future more thought will be given to the question before a decision is made to install individual-drive machines or group drive.

There is evidence that the unquestioned acceptance of the hydraulic principle for operating machine-tool mechanisms, current during the last few years, is at last waning, and here again the decision in respect to the type of drive will be influenced more strictly by the economic and mechanical features.

The advent of a completely automatic inspecting machine dealing with the size, finish, roundness, parallelism, and weight elements in the inspection of wristpins for automobiles marks the birth of a new principle in mass-production manufacturing. The exhibition of this machine at the Century of Progress Exposition in Chicago, and its use in the works of a well-known automobile factory, provides evidence of the possibilities for the development of this system in shops where a really complete mass-production program is in general use.

The Executive Committee of the A.S.M.E. Machine Shop Practise Division has noted with satisfaction the efforts which are being made to determine standards of machinability, but the industry is still a long way from the point where the element of machinability can be written into a commercial contract with any degree of confidence. It is planned to inaugurate further study of this element during the coming year.

CUTTING FLUIDS

Under the auspices of the A.S.M.E. Subcommittee on Cutting Fluids, a report dealing with the influence of cutting fluids when sawing various metals was presented by O. W. Boston and C. E. Kraus at the 1933 Annual Meeting of the Society. Nine metals were cut under standardized conditions, each with eleven different cutting fluids. The sawing was performed under a constant feeding pressure, and the time to saw off a given sized section of each metal was recorded. These data were to show the influence on the time rate of cutting of the different classes of oil.

Additional experiments involving various types of cutting fluids are now being carried on in the Metal Processing Laboratories at the University of Michigan, as follows:

(1) To determine the influence of the cutting fluid on cutting temperatures and tool life in turning.

(2) To determine the coefficient of friction for cutting fluids at different loads up to 3500 lb per sq in. for each of several speeds.

(3) To determine the influence of the cutting fluid on the torque, thrust, wear, and tool life of small drills operating in various materials.

It is expected that when these experiments are completed the results may be coordinated with those obtained in the sawing experiments as well as those reported on previously in connection with drilling, to the end that a hypothesis can be developed and definitions and specifications can be established.

The advent of the new grinding wheel impregnated with diamond dust records another forward step in the attack on this problem. However, the evidence at hand suggests that there is still much experimental development work ahead of the industry before a truly automatic and economically desirable machine, capable of handling milling cutters of large diameter can be placed on the market.

HYDRAULIC VALVES *and* GATES *for* BOULDER DAM

Part V—The Erection of the Bulkhead Gates and Their Hoisting Mechanisms

By P. A. KINZIE[1]

INASMUCH as the diversion tunnels had to be left open, with river flow unimpeded while the gates[2] were being installed in anticipation of the date when the river flow would fall to so low a value that they might be lowered one at a time, their seals fitted in place, and their operating mechanisms given an initial trial, it was essential that an erection program be worked out in complete detail to insure that this work could be performed to the best advantage. Much thought and study were devoted to the design and construction of the gate structures as well as the gates to insure that this result would be brought about.

A comprehensive construction and erection program and procedure was developed, divided into three main headings, and then fully explored in detail, as the result of which a carefully prepared indexed and cross-referenced volume known as "Technical Memorandum No. 301" was mimeographed and forwarded to the project. This volume contained 45 pages of printed directions and instructions for concrete procedure in constructing the bulkhead-gate structures, field-erection notes for steel work of the bulkhead gates and frames, and operating instructions for the gate hoists and control mechanisms. The memorandum included 43 drawings and was quite a formidable document. In it was given the weights of all the principal parts, the sequence in which they should be swung into place, recommendations as to bolting and riveting procedure, and methods for obtaining the alignment of parts and for installing and adjusting the seals. The quantities of water for filling and for operating the hoist cylinders and control systems were given, and there was included a carefully prepared set of instructions for the draining and supplemental steps that should be taken subsequent to the trial operations of the equipment to insure that it would be maintained in the best possible condition during the long period of inactivity that would ensue prior to final closure.

To accomplish this contruction and erection work to the best advantage it was necessary to erect the gate frames with their roller tracks and embedded reinforcing beams in the form of self-contained and self-supporting structural-steel towers 56 ft high. The members comprising these were proportioned and arranged to provide the stiffness and rigidity required to preserve the accuracy of the roller track's alignment. The concrete forms were erected around and attached to these members and the concrete was poured in successive lifts up to and including the heavily haunched concrete beams which would later carry the erection floors.

It was essential to take every reasonable precaution to make sure that the roller tracks were plumb and in correct relative alignment, as they are to be the base lines to which the gates will be erected and ultimately will be subjected to the heavy loading when the water stands 300 ft above the tunnel floors. As one means of insuring this, heavy steel-slab base-plate footings 3 ft 4 in. by 3 ft 6 in. by 3 in. thick, finished upon their upper faces were carefully leveled and were embedded flush in the concrete of the portal floors to receive the

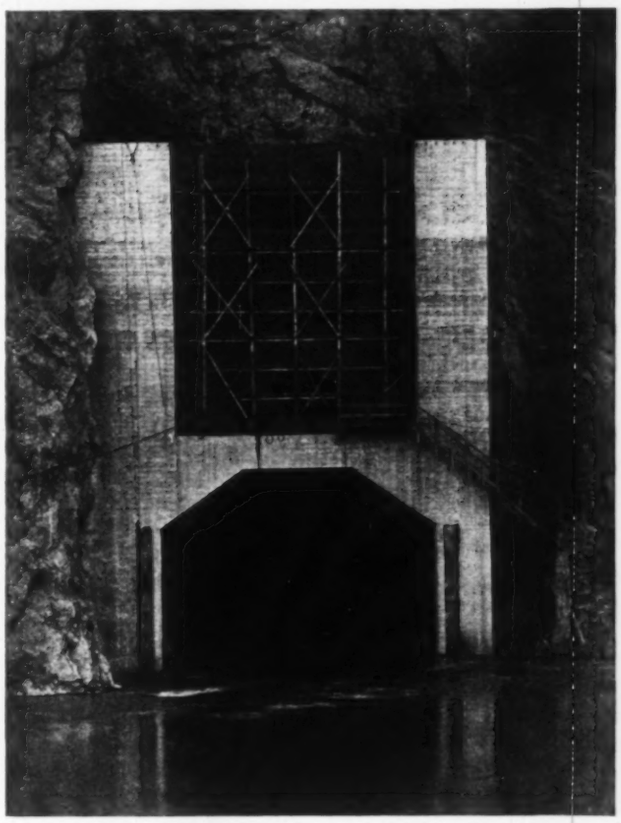


FIG. 1 BULKHEAD-GATE STRUCTURE PARTIALLY COMPLETED WITH LEAF ASSEMBLED ON ERECTION PLATFORM

(The river is flowing into the 50-ft diversion tunnel behind the gate structure.)

[1] Engineer, U. S. Bureau of Reclamation, Denver, Colo.

[2] The gates were described in the November issue.

Presented on "Reclamation Bureau Night," at the Semi-Annual Meeting, Denver, Colo., June 25 to 28, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Published by permission of the United States Bureau of Reclamation. Parts I, II, III, and IV appeared in the July, September, October, and November issues, respectively.

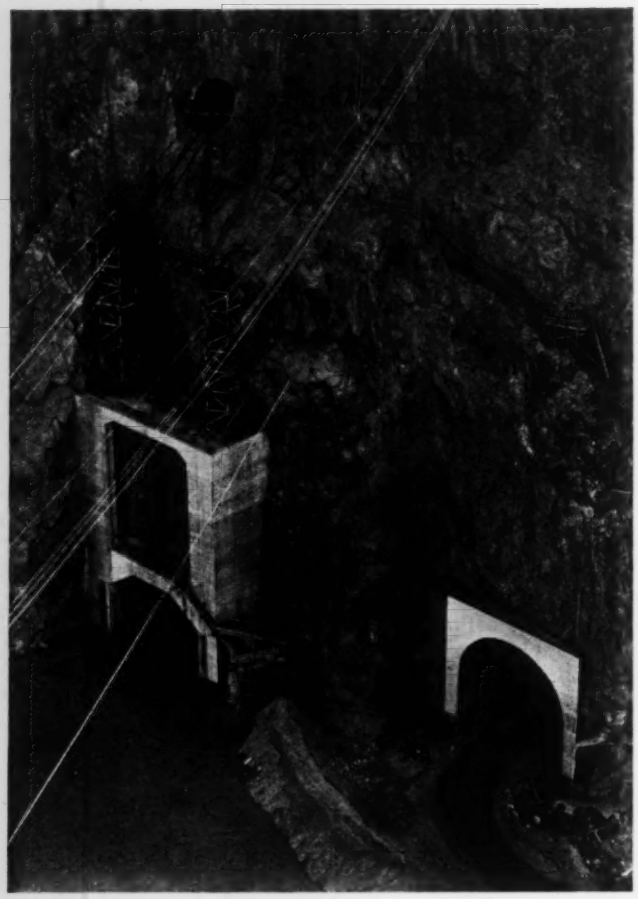


FIG. 2 THE PRACTICALLY COMPLETE GATE AND STRUCTURE ON THE ARIZONA SIDE OF THE RIVER

(Timber stagings are erected around the two vertical hoist cylinders. The operating panel shows faintly midway between the bases of the hoist cylinder. The gate leaf can be seen in the aperture of the concrete structure below the operating platform. The precipitous nature of the canyon walls is very evident. A truck is emerging from the right-hand tunnel portal.)

milled ends of the track members, and similar plates of smaller size were provided for the other vertical members as well. As finally worked out it was found necessary to provide 24 Carnegie beam sections 33 in. deep by 6 ft long, weighing 200 lb per ft, with twenty 6-in. by 3½-in. by 3.4-in. angles in pairs with outstanding legs back to back riveted as stiffeners to the web of each beam. The ends of the angles are milled to bear on the beam flanges. These 24 beam sections are to transfer the water loadings from each roller track into the portal concrete and to distribute these loadings over sufficient areas to insure unit pressures which will not progressively crush the concrete and so cause ultimate failure of the structures.

The base flanges of the roller-track members were bolted to the flanges of the 33-in. beams. Laminated shims were interposed for final adjustments prior to the pouring of the supplemental concrete used to encase the fixed wedges and the stems of the roller tracks after the gates had been lowered for adjusting the wedges and seals and raised again to their upper positions to await final closure.

It was also necessary to erect the concrete portal structures in three stages above the diversion-tunnel floors at elevation 640. The first stage was to the gate erection floors at elevation 696, whose heavy reinforced-concrete beams spanned the space six feet above the tunnel portals and afforded support for the structural-steel beams shown in section *A-A* of Fig. 17,[3] on which were laid and bolted fast the special construction beams (20) and (21*A*), provided with gusseted bolting flanges. These were carefully leveled and aligned to receive and support the bottom cross girders of their respective gate leaves. By this arrangement the gates were entirely assembled and riveted with the river flowing freely through the tunnels below.

In the design of the erection platform and its supporting reinforcing beams, advantage was taken of the fact that as the leaf was erected on this platform to a height that would include the bottom cross girder, the two next adjacent cross girders above and the complete cover plates, spacers, struts, and skin-plate structures associated therewith, and as these parts had been bolted up in an adequate manner, the cooperating members therein would act as a horizontal beam spanning the space between the concrete tower legs. Therefore the concrete beams carrying the erection platform had to be capable of sustaining only the weight of these members while they were being assembled. This was found to be 390,000 lb plus the weight of the platform and miscellaneous erection equipment and the weight of the concrete beams themselves. For this reason the cross beams in the erection platforms are placed close together adjacent to the towers so that the weight of the completed leaf of each gate will be transmitted directly into the haunches below.

After the gate leaves were erected the forms for the remainder of the concrete structures enclosing them were placed and concrete was poured progressively to the construction joints at elevation 696.75. This stage of construction is illustrated in Fig. 1, where part of the river is shown flowing through the gloomy portal and into the tunnel beyond. The lowering cliffs of the canyon wall darkly outline the light-gray concrete portal structure, whose heavily haunched portal beams carry the nearly completed gate leaf seen between the concrete tower legs on either side. The seven levels of erection stagings are outlined against its front face.

After the gate leaves were completed and the toggle mechanisms assembled and riveted in place to the upper ends of the vertical girders, the remaining form work required for supporting the concrete construction of the operating platforms was erected on staging on the tops of the gates. The remainder of the concrete was then poured, after which the hoist cylinders and related control mechanisms were installed.

In Fig. 2 this work is shown practically completed. The two hoist cylinders encased in their criss-crossed timber erection stagings rise from the control platform above the gate and the structural-steel foot bridge connecting their tops is outlined against the canyon wall. On the operating platform between their bases the dark rectangular outline of the control panel with its pressure gages is seen. Below the gate leaf, seen in the paneled aperture, the sullen river flows, filling half of the dark portal entrance. The precipitous nature of the rock cliffs shows plainly and gives a good idea of the inaccessibility of these tunnel portals and affords a glimpse of the difficulties that had to be overcome when installing their structures.

In Fig. 3 is shown a "close-up" of the upper portion of the bulkhead structure on the Nevada side of the canyon. The upstream face of the leaf framed in the aperture, the heavily haunched concrete beam with its pipe railing spanning the portal yawning black in the bottom center of the picture, and the man climbing the ladder rungs embedded in the vertical pylon face on the far side of the structure, all serve to convey a sense of the size and massiveness of these installations. The up-

[3] Fig. 17 appeared in the November instalment, p. 658.

stream face of the gate leaf with its riveted cover plates shows clearly here. In the upper portion of the picture the operating platform with its pipe handrail appears, and extending upward from this platform, immediately above the left-hand side of the gate leaf, is seen a portion of one of the two hoist cylinders with the timber erection staging encasing it. The two pipes that extend from the top chord of the double-track railway bridge to the operating platform above supply water under pressure for operating the hoists.

Inasmuch as it was apparent that a hoisting capacity of well over 1100 tons would have to be provided for operating each of these gates, and as it was most desirable to employ the hoisting equipment for operating the toggles after the gates were closed, it was evident that cable types of suspension and operation would be very complex and expensive. Hence, other alternatives were investigated to determine the equipment that would be most appropriate for the governing conditions and after a number of these had been examined and estimated it was decided that a pair of hydraulic cylinders operated by water pressure would most nearly satisfy those conditions.

At the time that the designs were completed and fabrication of the hoists had been started the plans for the canyon-wall outlet works contemplated the use of 72-in. needle valves and it was the intention to salvage the hoist cylinders after the bulkhead gates had been finally closed, and use them as conduit liners behind these valves. For that reason 91 in. was chosen as the inside diameter of the hoist cylinders. The general assembly and construction drawing is reproduced in Fig. 4.

Designs for the gate hoists were predicated upon a gross lifting capacity of 2,737,000 lb with a maximum water pressure of 220 lb per sq in. beneath the pistons, while a downthrust of 1,300,000 lb was required to operate the toggle mechanisms for seating the wedges.

The stems were accordingly designed for 2,737,000 lb in tension and 1,370,000 lb as column loadings due to 100 lb per sq in. maximum working pressure above the pistons.

In order that the gate leaves might be lifted free of their erection platforms while these were being dismantled and removed preparatory to lowering the gates for their trial operations it was found that a total gate travel of 59 ft 6 in. must be provided and a further travel of 2 ft $9\frac{3}{8}$ in. was required for the operation of the toggle mechanisms. For good measure a total piston travel of 62 ft 5 in. was provided.

To meet these conditions, tubular stems 19 in. outside diameter by $15\frac{1}{4}$ in. inside diameter by 67 ft $4\frac{3}{8}$ in. long, weighing 25,400 lb each were required. The stems are steel forgings turned and polished outside and rough-bored inside, made from the standard specifications of the American Society for Testing Materials for carbon-steel and alloy-steel forgings, class C, serial designation A-18-30, and they were thoroughly annealed before machining.

One of these hoist stems is shown on blocking in the left foreground of Fig. 5 with a machinist in the middle background "miking" its diameter. In the bottom center foreground the ends of the other three stems are seen. In the center distance are three hoist-cylinder unit castings.

In preparing the specifications for these hoists, three means of hoist-cylinder fabrication were permitted, viz: cast steel, seamless forged steel, or welded plate steel. The low bid for these hoists was for cast-steel cylinders and was accepted. Each completely assembled hoist cylinder is 64 ft 6 in. long (not including head or base) and consists of eight units each 8 ft $\frac{3}{4}$ in. long with their companion flanges faced, shouldered, drilled, and bolted together as shown in Figs. 4 and 6. Each of these eight units weighs 11,125 lb. They were finish bored and then ground inside to a smooth finish.

Each cylinder is provided with a domed and ribbed cast-steel piston. The construction of this piston and the method of attaching it to its stem are shown in Fig. 4. These pistons are provided with bronze piston rings adjacent to their lower edges which scrape the cylinder walls clean as they descend in advance of the soft-packings' passage. The packings are installed above these rings and consist of two sets of oppositely facing chevron-type packing. A bronze follower ring with adjusting studs keeps this packing in place.

The method of sealing the pistons was selected only after many others had been developed, examined, and found wanting through one cause or another. The conditions of operation which this piston-sealing equipment must successfully meet are exceedingly severe, and their failure to function properly when called into service would entail consequences of a gravity difficult to realize or describe. Each piston casting weighs 13,000 lb.

The upper cylinder heads are domed and ribbed steel castings, constructed as shown in the large-scale sectional assembly in Fig. 4. The design of these heads required much study owing to the peculiar operating conditions which they must withstand. One outstanding feature was that each had to carry one-half of the total weight of the bulkhead-gate leaf and associated moving parts, representing a concentrated load of more than 1,100,000 lb, transferred from the under annular-ring face of each of the stem nuts on to their upper external surfaces in the manner as shown in Fig. 4.

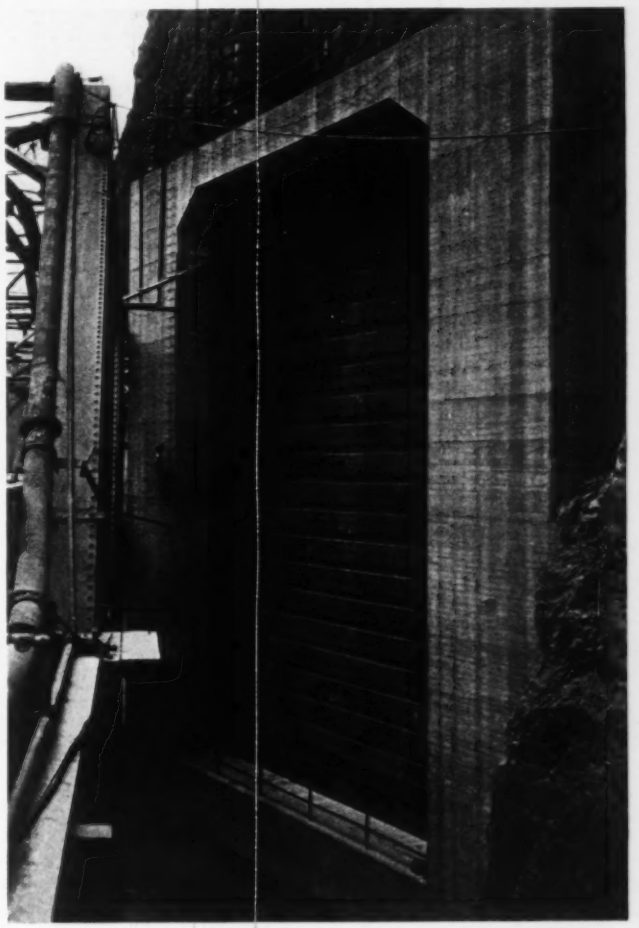


FIG. 3 A PORTION OF THE NEVADA GATE AND STRUCTURE
(The face of the gate is seen inside the opening in the center of picture.)

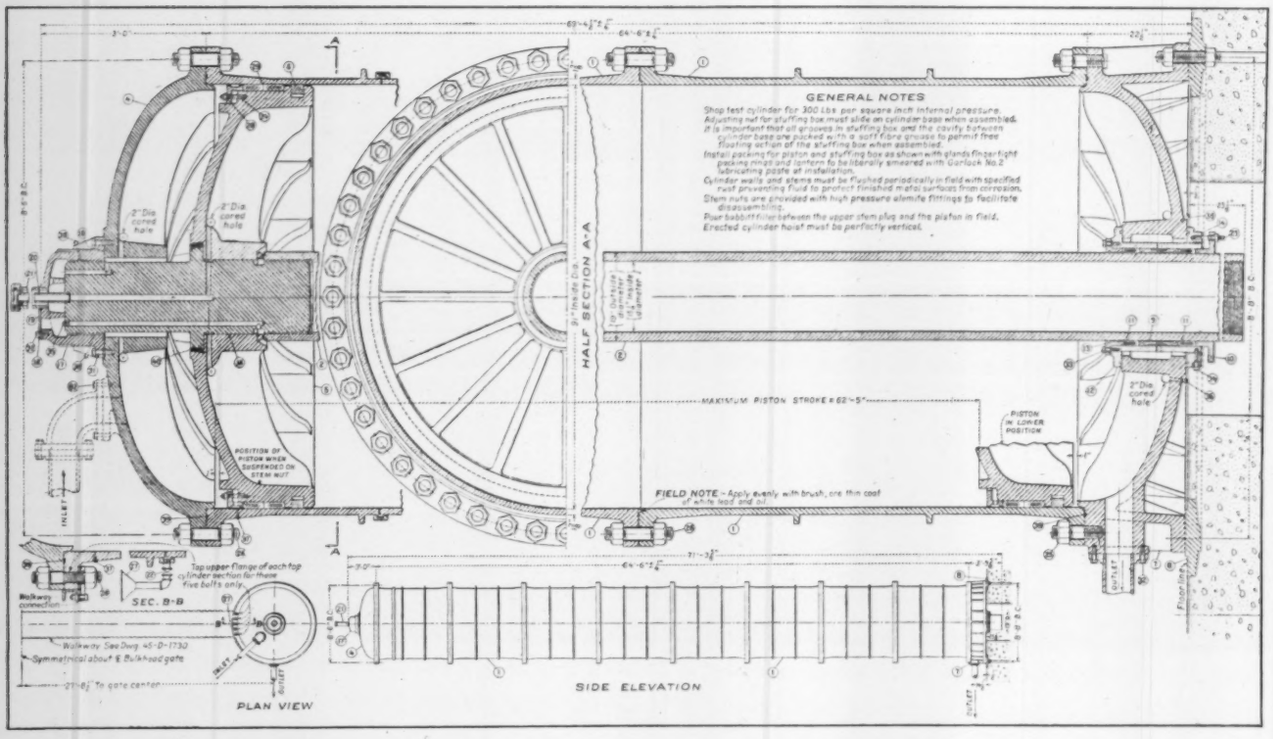


FIG. 4 HYDRAULIC HOIST CYLINDER ASSEMBLY AND SECTIONS

Suspending the gates from the stem nuts resting upon the upper cylinder heads was essential in order to lift the gates off the erection platforms and hold them in their positions while the platforms were being dismantled and removed. This process requires several days owing to the cramped working quarters and the hazardous position and nature of this work.

The cylinder bases, which constitute the lower cylinder heads, are likewise domed and ribbed steel castings constructed as shown in Fig. 4. Each is provided with a central hubbed aperture within which the stem stuffing box is mounted. These stuffing boxes and their mountings are constructed so as to permit lateral movement responsive to stem deflections and gate displacements below and were the cause of many wakeful moments. The construction is clearly shown on the large-scale sectional assembly shown in Fig. 4. Each is provided with two oppositely facing sets of chevron-type packing with bronze lantern rings interposed between bronze stop rings above and bronze glands below. Each cylinder-base casting weighs 20,100 lb and is anchored to the concrete operating platforms by twenty-four $2^1/_2$-in. anchor bolts.

In Fig. 6, one of the completely assembled hoist cylinders, more than 70 ft in overall height, is shown lying on its side undergoing the shop pressure tests at 300 lb per sq in. in the yards of the Hardie-Tynes Mfg. Co., of Birmingham, Ala., fabricators of this equipment under Government specifications 533.

Note the ladder resting against the cylinder base at left-hand end of picture, giving access to the pressure gage on upper side of the base. The bolted flanges of the eight unit castings composing the complete cylinder show prominently here.

In choosing the twin-hydraulic-cylinder type of hoist for operating the bulkhead gates, the flood-gates of rhetoric, criticism, and dire prophecy were unloosed. The chief contention by those inclined to oppose such procedure was the unprecedented size and the so-called "impossibility" of synchronizing the cylinders at opposite sides of the gates (spaced on 55 ft 5 in. centers) so that they would function in unison and maintain their respective gate leaves on an even keel.

In reviewing these contentions and criticisms in an effort to judge their soundness and truth, the fact that the operating speed could be made quite slow (about 75 min for raising each gate and about 45 min for lowering) or approximately one foot per minute, vitiated much of their virtue and pungency. It could be seen that by exercising reasonable ingenuity the movement of the leaf itself could be made to stabilize the actions of its two hoist cylinders so that they would act practically as one unit by diminishing the amount of flow into the cylinder which tended to move too rapidly and increasing the flow into the sluggish cylinder. It was evident that this could be made to occur automatically.

With this fundamental purpose in view designs were started on control equipment to produce the desired results. In the preparation of these designs it was decided that the control panel would be placed midway between the bases of the hoist cylinders on the control platform 119.5 ft above the tunnel inverts. Thus ample time will be available after the gates have been finally closed to disconnect and salvage this equipment before the rising water reaches that elevation. It was also decided to arrange the controls so that the automatic feature could be changed to manual operation whenever the operator desired to do this.

The designs for this control mechanism as finally adopted are shown in the general assembly of this equipment in Fig. 7, in Fig. 8 which shows the panel-board assembly and its associated mechanical drives, etc., and in Fig. 9 which shows the detail assemblies of the control piping, control valves, etc.

In Fig. 7 the general assembly of the control mechanism is shown with the gate leaf in the raised position suspended by the hoist stems connected to the toggle mechanisms in the manner as shown in the elevation and in the end elevation. The

FIG. 5 ONE OF THE 19-IN. HOIST STEMS APPEARS ON THE LEFT RESTING ON BLOCKS ON THE SHOP FLOOR

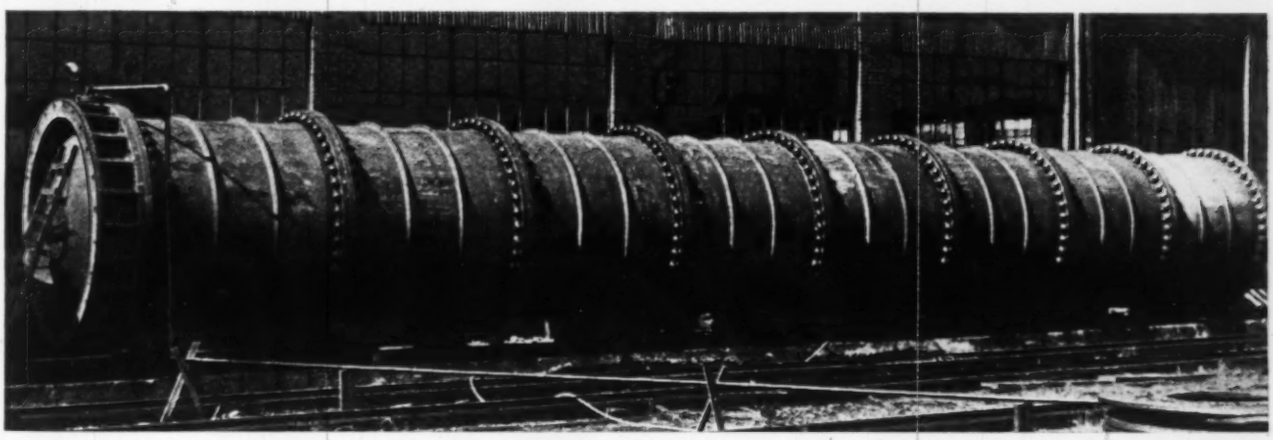


FIG. 6 COMPLETELY ASSEMBLED HOIST CYLINDER ON ITS SIDE UNDERGOING PRESSURE TESTS
(Note ladder at left end to give access to pressure gage on cylinder base above.)

control panel with its dials, gages, hand wheels, and other equipment is seen midway between the bases of the hoist cylinders. Beneath its supporting concrete platform are seen the sheaves, brackets, and the interconnecting wire ropes which extend between the gate leaf and the operating mechanism above. In the plan view of this figure the relative arrangement of the principal piping can be seen.

In the views of Fig. 8, the control-panel assembly, the general arrangement of the pilot valve, indicator dial, and evener mechanisms with their rope drums, chain sprockets, interconnecting rods and shafts, and their upside-down pendulum mountings are seen in their relative positions with respect to the main diaphragm-operated valves and associated operating equipment adjacent to the control panel.

The control mechanism consists of the evener mechanism, whereby the gate is maintained in a level position as it is raised or lowered; the position indicators, which show its position in feet and fractions from its upper and lower positions; the spot indicators, that show accurately when the gate is seated and likewise when the toggle-driven wedges have been driven home into their final positions; the evener dial, which shows when the gate is riding level, and likewise any deviation from even balance; and the pilot valves, reducing valves, and pressure gages.

In Fig. 10 the control panel and associated piping, valves, etc., are shown installed on the operating platform of one of the gate structures.

The gate-position indicator dial is seen to the right of the

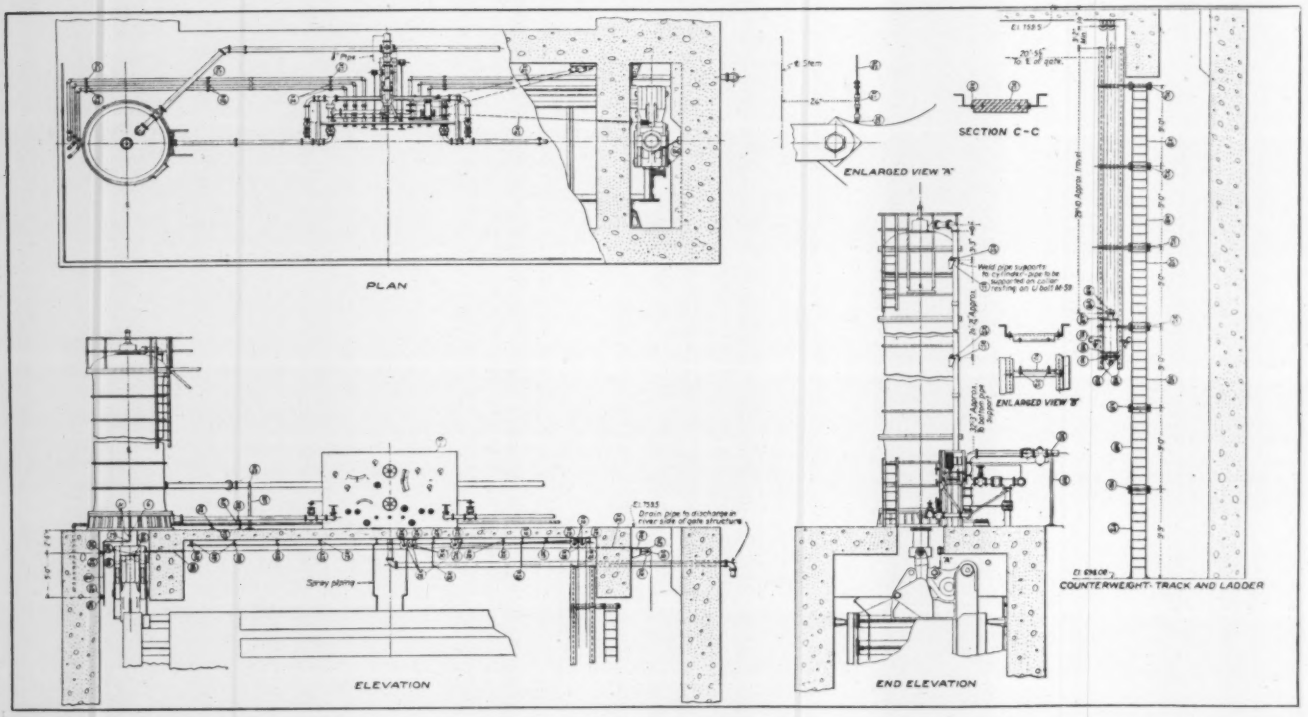


FIG. 7 GATE-CONTROL ASSEMBLY

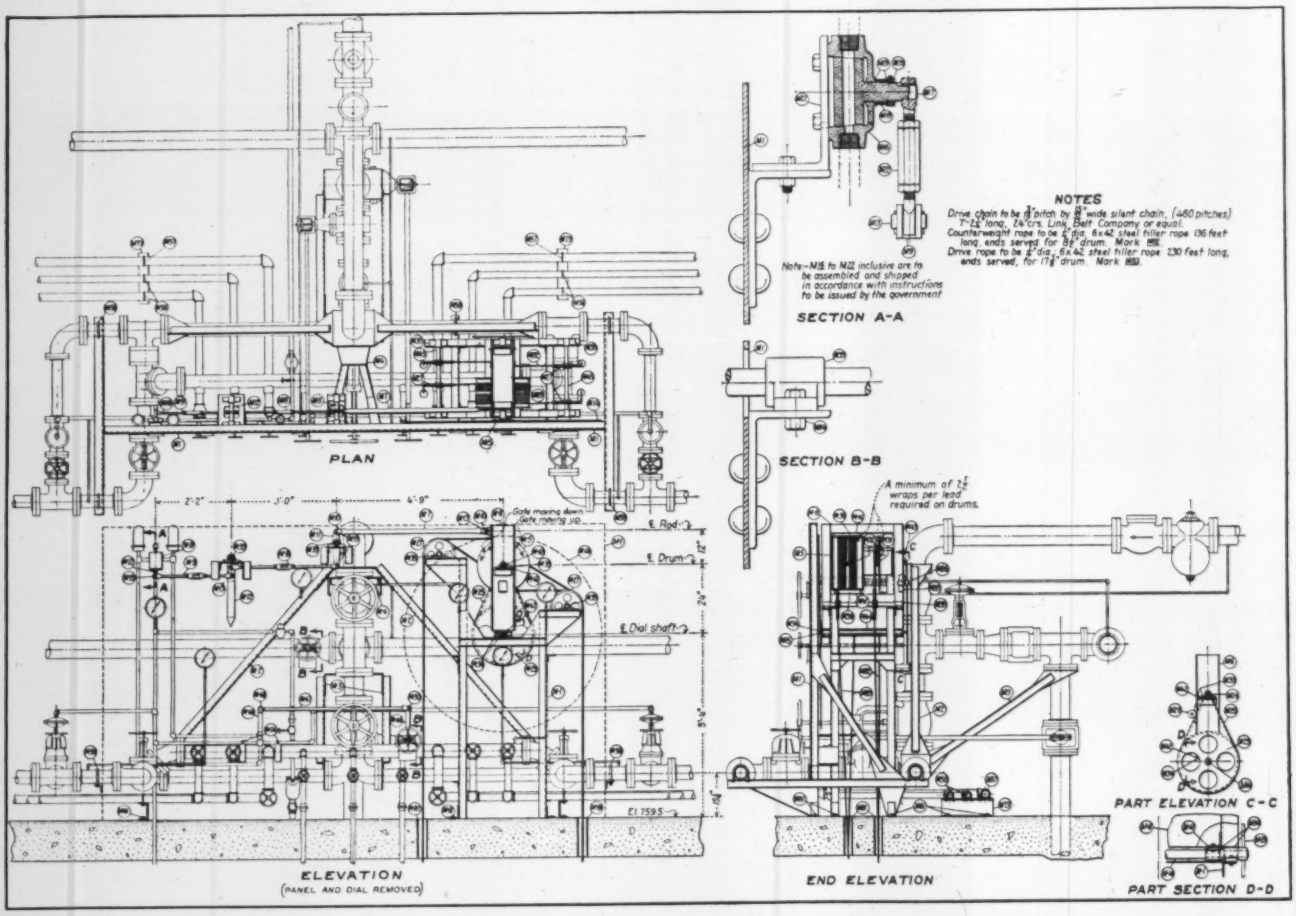


FIG. 8 CONTROL-PANEL-BOARD ASSEMBLY

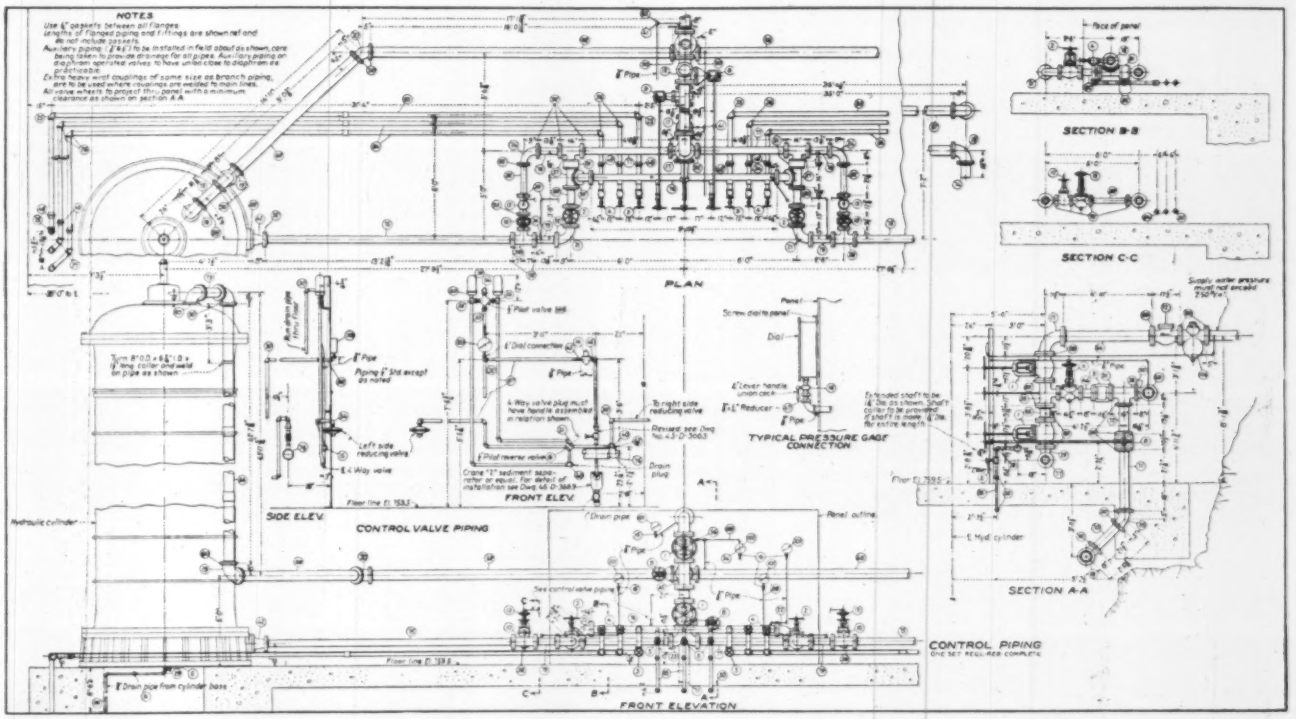


FIG. 9 CONTROL-PIPING ASSEMBLY

center of the panel. To the left center is the evener dial whose pointer shows when the leaf is level or otherwise. Below this is the reversing lever which switches the leads to the pressure regulators and pilot valve into correct sequence for raising or lowering the gate. The small handwheels in the lower portion of the panel control the jet pipes for removing the sand under the corner filler slabs when final closure is being effected, so that the gate leaf can be seated. In the central bottom portion of the control panel are the valve handwheels which control the spray piping system used in cooling the leaf prior to final closure. At each end of the panel are two gate valves which are used when direct manual control is desired. The operator is adjusting one of these at the far end of the panel. Just to the left of his hands is the upper portion of the diaphragm-operated valve controlling the line running to the base of the hoist cylinder in the background behind him. The mating diaphragm-operated valve is seen at the left-hand end of the control panel.

In the right-hand background behind the operator is the base of one of the hoist cylinders. In Fig. 11 the base and lower part of the same hoist cylinder is seen with the erection scaffolding still in place around it. It is this timber scaffolding that shows in Fig. 2. The bronzed attendant, stripped to the waist, follows the dictates of comfort and conforms with the common practise of that hot, dry country. Comparing the details of the picture with the husky individual standing in the midday sun will give about as good an idea of the real sizes involved as can be secured in any way other than actually seeing the parts themselves. No amount of verbal description can adequately convey true concepts of size which will not be immediately discarded when these structures are viewed for the first time. Some further measure of comparison may be gained from the fact that from the tops of these cylinders high above the operator's head to the gate sills and tunnel floors 119 ft below where the operator is standing is substantially the same as the height of a modern 18-story office building.

The evener apparatus of the control mechanisms for both gates and the remainder of the control mechanisms are alike in all respects. This apparatus is so arranged that each gate leaf will be kept level while it is being raised and lowered. It also synchronizes the final setting of the movable wedges so that they are forced home simultaneously upon final closure.

This is accomplished by attaching $^1/_4$-in. wire tiller ropes to the yoke cranks of the toggle mechanisms on each side of each gate in the manner shown at "*A*" in the end elevation so Fig. 7. This attachment is shown in the enlarged view "*A*" on this same drawing. The tiller ropes are carried upward from these points of attachment to suitable idler pulleys on the underside of the concrete control platforms as may be seen in the elevation in Fig. 7 and into the mechanism behind the control panels as shown in the plan, elevation, and end elevations of Fig. 8. Here they simultaneously over- and underwind on a single drum mounted in an inverted swinging pendulum frame in the manner shown in the elevation of Fig. 8, where a high-ratio chain-driven speed increaser magnifies any relative movement of one side of the gate with respect to the other, and actuates the plug-type pilot valve shown in enlarged detail assembly in section *A-A* of Fig. 8. Water from this pilot valve is supplied to the diaphragms of the two balanced regulating valves seen in the right- and left-hand portions of the plan and in the elevation of Fig. 8. These valves govern the flow through the pipes connected to the bases of the hoist cylinder. By throttling the flow to the cylinder whose piston is moving too fast, and by opening up on the other, equal and uniform travel of both is automatically secured. The rates of travel of both sides of the gate are equalized by regulating the velocity of flow to or from the interiors of the hoist cylinders beneath the pistons.

A counterweight is suspended beneath each control platform to keep the operating ropes tight at all times.

Suitable reducing valves are arranged in the piping system to prevent excessive pressures from being introduced into the hoist

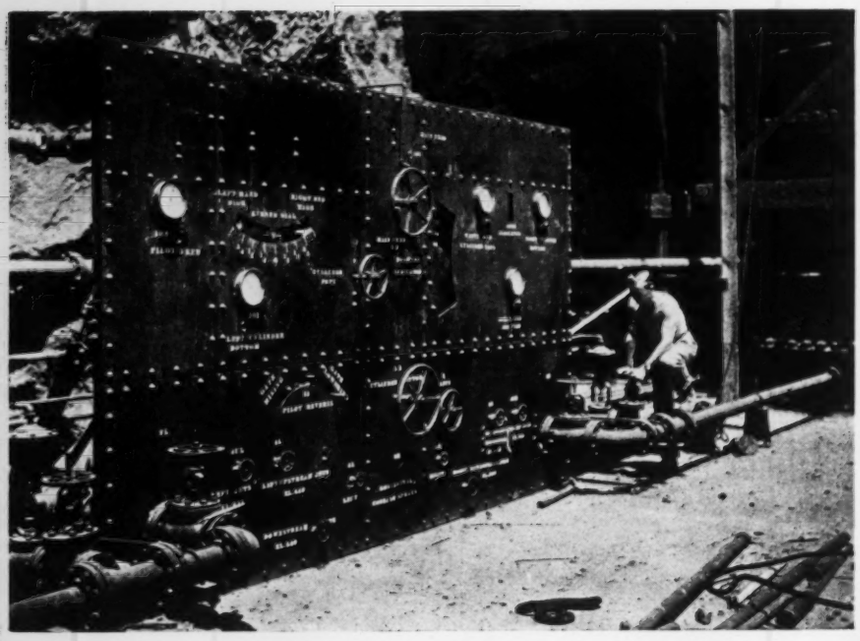


FIG. 10 CONTROL PANEL IN FINAL POSITION WITH ALL PIPING AND CONNECTIONS COMPLETED
(The functions of the various parts are designated by the white stenciled lettering on the panel. This panel shows faintly in Fig. 2.)

cylinders in either raising or lowering the gate or in setting the wedges.

In Fig. 9 the complete control-piping assembly for one gate is shown with all the valves and special equipment employed in the hydraulic system, so that the flow lines for any condition of operation can be traced out. This drawing shows the connections to the upper cylinder heads and to the cylinder bases, pilot valves, and diaphragm-operated valves, and also the manually operated valves used for direct manual control.

Iron and steel exposed to the fierce rays of the sun in that arid region within which Boulder dam is located soon reaches a temperature that is painful to the touch and which often becomes unbearable. Inasmuch as the metal work in these gate leaves will be subjected to those same intense and scorching rays, it was found that it would be necessary to cool the metal prior to making final closure so that it would not suddenly contract on coming into contact with the river water as the gate leaves were progressively submerged. To accomplish this, elaborate spray-pipe systems have been installed above and within each gate leaf so that they may be cooled as nearly as possible to river-water temperature prior to final descent. Control of these spray-pipe systems is from the central operating and control panel shown in Fig. 10.

In effecting final closure of the gates one problem is involved which for a time threatened their successful use. Briefly, the condition is as follows: The gates will probably have to remain in their open positions with the river flowing through the tunnels below for more than two years. During this period boulders and other solid material will be passing through the structures in large quantities. Inasmuch as the gates will probably have to be closed with the water 60 ft deep over the sills, the resulting currents will make grappling or dredging operations to free the lower-gate-seat corner recesses of the boulders and other obstruction which will inevitably accumulate there practically impossible. However, it is most essential that these corner areas be freed of such obstructions if successful closure is to be accomplished.

Much earnest thought was devoted to securing a workable solution to this problem and many angles of attack were tried with but poor results at best. Skimming weirs were planned and abandoned. Bottom transitions from square to round were tried, and then it was found that the resulting concrete portal structures could not be reinforced sufficiently to carry safely the 300-ft water load that would ultimately come upon the gate leaves. Designs of a gate leaf with a half-rounded bottom which would make the corner depressions unnecessary were tried and discarded and others too numerous to mention were investigated and found to be equally futile.

Finally, when hope was beginning to wane, a solution was found that would satisfy these critical conditions with reasonable certainty, and its simplicity was rather startling. By referring to Fig. 12 the apparatus employed to overcome this difficulty will be readily understood. In this figure are shown the corner-filler-slab

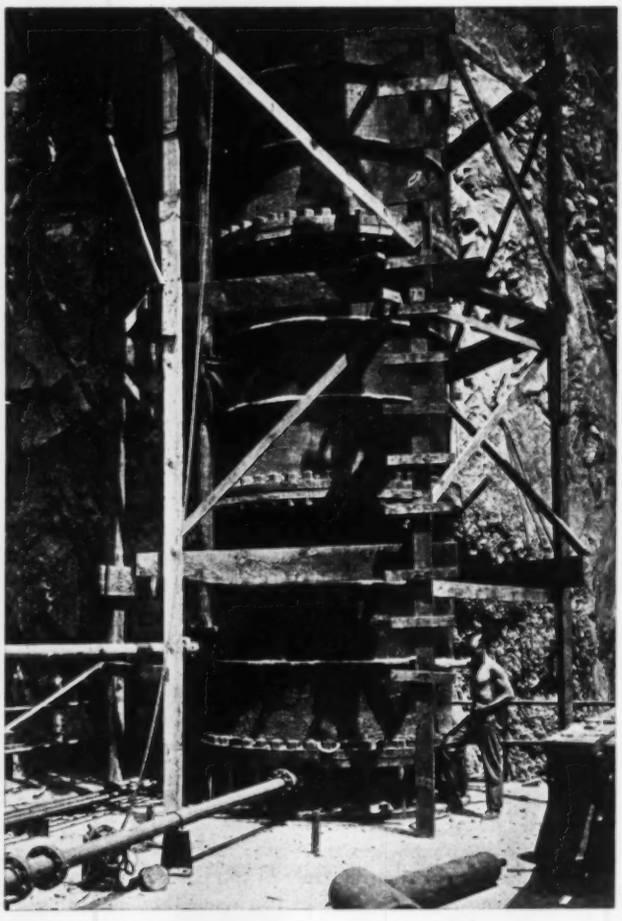


FIG. 11 THE BASE AND LOWER PORTION OF A HOIST CYLINDER SURROUNDED BY ERECTION STAGING
(This is one of the two cylinders visible in Fig. 2.)

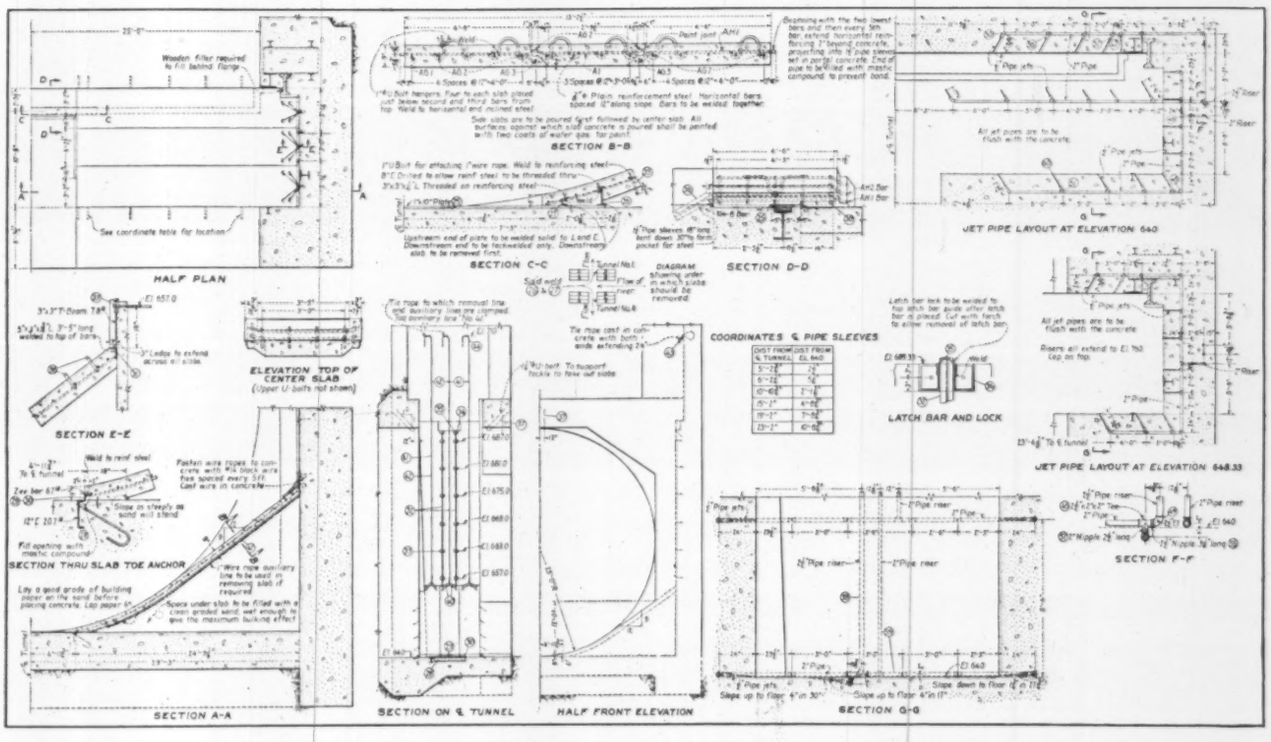


FIG. 12 CORNER-FILLER-SLAB ASSEMBLY

assembly and details of construction and placing, the self-releasing hinge-anchorages in the tunnel floor, the heavy wire snaking ropes for removing these slabs, and the jet-pipe systems embedded in the concrete portal structures for disposing of the sand after the corner filler slabs have been stripped or "peeled" off leaving the supporting sand exposed.

The two symmetrical triangular-shaped recesses formed by the circular tunnel portal in the vertical wall face, one of which is shown in section *A-A* of Fig. 12, are filled with fine sand. Thin heavily reinforced concrete slabs 9 in. thick are then laid on top of this sand in each corner so that the upper exposed surfaces are continuous with the lower portions of the circular tunnel beyond. This fills the recesses so that there is no place where boulders or other debris may lodge.

The concrete slabs are carefully sealed to the adjacent concrete structures so that the flowing water cannot gradually carry away the sand that lies beneath them. When the time for final closure arrives the gate leaves will be lowered part way and the steel cables will then be used to withdraw the slabs. Then an elaborate set of jet pipes embedded in each concrete structure will jet the sand away as the gates descend. So the final act in the subjugation and harnessing of the mighty Colorado River will have been finished, for when these gates have been lowered to final closure, as will be done early in 1935, this river, which has so long been a haunting menace to the fertile lands below, will no longer be a free agent, but instead will become for the first time the slave of man.

When final closure has been accomplished, feverish salvage activities will immediately begin in an effort to save the hoist cylinders, pistons, heads, bases, etc., the control panels and piping, and all other metal work possibl within the two- or three-day period which will elapse before the rising waters reach the operating platforms. As for the gates and their frames, they will remain buried like the caverns of Kublai Khan.

The pictures showing the shop assembly of the gate leaves were furnished through the courtesy of the Consolidated Steel Company of Los Angeles, Calif., who fabricated the gate, leaves, and frames under Government specifications No. 533, while the pictures of the shop assembly of the hoist cylinders, likewise the hoist stems, were furnished through the courtesy of the Hardie-Tynes Mfg. Co., of Birmingham, Ala., who fabricated the gate hoists under Government specifications No. 533.

The gate structures, gates, hoists, control mechanisms, and associated mechanisms were completed late last fall and were then operated to insure that all parts functioned satisfactorily and to permit the final fitting of the sealing equipment in the closed positions. As a result of these trials and tests the field engineers reported that "they work like a Swiss watch." They now stand ready and waiting for the "zero hour" which will probably arrive some time in February, 1935, when they will make their final descent.

The author wishes to thank J. L. Savage, the chief designing engineer of the Bureau of Reclamation, who, despite the burdens that are continuously imposed upon him, managed to steal sufficient time off to read these papers and give much valued advice in their preparation.

He also wishes to pay sincere and honest tribute to all those willing, loyal, fellow workers in the office and field, too numerous to name individually, who cheerfully labored through the days and often far into the night as well, for their unfaltering devotion and collective efforts that made possible the conversion of mere ideas into actualities.

All designs and investigations of the Bureau of Reclamation are under the direction of J. L. Savage, chief designing engineer. All engineering and construction work is under the general direction of R. F. Walter, chief engineer, with headquarters at Denver, and all activities of the Bureau are under Dr. Elwood Mead, Commissioner of Reclamation, Washington, D. C.

MECHANICAL ENGINEERING

Vol. 56 DECEMBER, 1934 No. 12

GEORGE A. STETSON, *Editor*

Finding Work

THE reception of the article in last month's issue, "Finding Work," has been gratifying, and as announced elsewhere, reprints are now available.

It is natural that Mr. Board's article should bring out other available material of a similar nature. One of these, "If You Want to Get a Job," by Newton D. Cook, manager of the San Francisco office of the Engineering Societies Employment Service, contains the instructions to those who apply to that office for help. It consists of seventeen tersely worded instructions designed to assist the applicant in concentrating on the most successful approach and to warn him against certain hazards. Attached to it is a sample personal record. There is also an original formula for testing the probable effectiveness of an application for employment. The instructions are mimeographed and the price is one dollar per copy.

Finding work for the unemployed engineers of the country is a staggering job. In New York, Chicago, and San Francisco, the Engineering Societies Employment Service has offices where tireless efforts are being made to bring man and job together. Increased appropriations to carry on this work have been supplied from time to time by the societies out of diminishing income. But no financial contributions can match in human values the services of the loyal men who have administered the work of the service. Regardless of what other reward may be theirs they are certain of a sense of satisfaction in being able to give assistance to brothers in distress. To their devotion and enterprise many an engineer owes the opportunity he has received of finding work.

A Cooperative Effort

THIS month the concluding instalment of an unusual paper is presented, "Hydraulic Valves and Gates for Boulder Dam," by P. A. Kinzie. No engineer, regardless of his present occupation, can look over these instalments without having his interest and enthusiasm aroused. Regardless of what he may think of the Boulder dam project, he cannot deny a word of praise for the manner in which the unusual problems of design and construction were solved. Reading Mr. Kinzie's very human story of the trials, and doubts, and hard-won conclusions will recapture for him his own experiences in overcoming obstacles. Mr. Kinzie's enthusiasm is typical of the joy of craftsmanship that every engineer has felt in work well done; and the spirit with which he attacked his job, so evident in his description of it, draws all engineers closer together in the reading of it.

It has been a long time since an article in MECHANICAL ENGINEERING has been so profusely illustrated with working drawings. If justification is needed, it will be found in the fact that an engineer likes to see how another man does a job. Undoubtedly many a magnifying glass has been perched over some of the minuter details of these drawings which a necessity for saving space doomed to great reduction. The application of welding, so beautifully illustrated in the first instalment, the precision in the manufacture of large pieces, many of them destined to withstand great pressures, the careful planning of details, the weighing of one solution against another, all provide their lessons. It is not necessary to build another Boulder dam to put to use the principles of design, construction, and operation that are involved in this project. Many an engineer, faced with what looks like pioneer work, will glean from Mr. Kinzie's experiences the needed principle or detail to make his own work more readily a success.

Without detracting from the Boulder dam achievement it is proper to call attention to the multitude of engineers, past and present, who contributed to its success. In the absence of established and reliable technique developed by others for other projects, many of the solutions worked out in the case of the Boulder dam would have been discarded as of unproved merit; and much of the completed design would have been impracticable had it not been for the shops where years of experience had trained designer and workman alike in the skill required to fashion metal accurately and economically. Mr. Kinzie is, in fact, the speaker for thousands of inarticulate fellow-craftsmen on drafting board, in laboratory and shop, and at the site itself, whose efforts provided these appurtenances to a great engineering achievement, and brought them together in a coordinated whole.

Po Desiti Letech

TEN years ago a group of Americans, expert in the practises and principles of management in this country, participated in the First International Management Congress, held at Prague, Czechoslovakia. The Congress was called by the new republic under the patronage of its president, Dr. T. G. Masaryk, and honorary chairmanship of Herbert Hoover, at that time Secretary of the Department of Commerce. To that country, recovering from the effects of the War and fired with a zeal to become of industrial importance among western peoples, the participants from the United States and Europe brought the inspiration of their faith in modern industrial management and many papers that had been selected to give the Czechoslovakians information about recent progress in that art. That the Czechoslovakians were appreciative and grateful was evident from the enthusiastic reports of the reception accorded the participants in the Congress and the honors bestowed upon them. Now, a pamphlet, printed in a number of languages and entitled "Po Desiti Letech" (after ten years), has been

published by the Masaryk Academy of Work, Prague, in commemoration of that first congress. It contains comments prepared by many of those who contributed the papers ten years ago.

The names of Taylor and Gantt appear frequently throughout these pages, just as they did in the papers read ten years ago. They recall once more the fundamental contributions of these men to management and the position of leadership which the United States and The American Society of Mechanical Engineers have held in industrial development.

In our own country, recovering from an economic depression and faced with fundamental problems of industrial philosophy which provide ample opportunity for intelligence and sagacity in management, the capacity for analysis, interpretation, and intelligent action is needed more than ever before. The impacts of social and economic forces—to say nothing of political—have been severe. In phrase if not in fact industry faces the opportunity to govern itself. Is it too much to hope that the principles of sound management—honestly determined costs, intelligently administered budgets, realistic market surveys, enlightened self-interest in relations with competitors, labor, and consumers—to mention but a few—may be applied to groups of plants in trade associations and under code authorities, and eventually to the entire coordinated complex of industrial life as effectively as they have to individual plants?

Contributions of Management

THIS present issue should serve once more to emphasize the importance of the relations of industry and management as coordinated by the engineer, and to indicate the extremely practical interest which engineers have in economic and social problems.

For example, an unusually readable report on progress in industrial management in 1934, prepared by the Management Division of the A.S.M.E., directs attention to some of the questions that are before managers of industrial establishments today and reports the trend of current thinking and practise. Seldom have these problems been so acute or needed such skill and intelligence in their study.

In addition to this general survey, which, because of lack of space, could not be presented in full, there are three papers which this division had prepared for the Annual Meeting. The paper by Virgil Palmer is a companion piece to that by Professor Dickinson published last month. While Professor Dickinson's paper dealt with employee suggestion systems in general, Mr. Palmer's is a description of the system in operation at the Kodak Park Plant of the Eastman Kodak Co. In days of an awakened consciousness of the position of the wage earner in industrial establishments, the subject is a timely one, and both papers should prove helpful to industrialists and personnel managers.

Two other papers indicate the invasion of statistical methods into industrial life. Dr. Shewhart, whose reputation for the application of such methods to the problem of quality control in production has been based on his interesting work for the Bell Telephone Laboratories and his numerous writings, has provided what may be termed a philosophical approach, while Professor Brown has shown the possibilities of the method when applied to distribution. Both papers indicate how the application of a little mathematical theory leads to clarification and a simplification of the problems of mass production and mass distribution. An extension of the use of the statistical method in industry is indicated.

Although not an Annual Meeting contribution, the paper by George W. Kelsey is an appropriate companion to that by Professor Brown. It deals with the application of engineering principles to the problem of marketing and is written with a view to organizing a general procedure for engineers who are faced with the necessity of introducing a new or an improved product.

Finally, R. E. W. Harrison, in a report for the A.S.M.E. Machine Shop Practise Division, adds further evidence of the major importance of economic factors in industrial and engineering enterprises. It is safe to predict that as the engineer extends his influence further into the conduct of industrial enterprises, he will be forced to give more and more attention to the economic and social implications of his work. Indeed, with the condition of industry as it is at present, these factors would seem to be of even greater importance than technological progress. For unless industry can survive and discover the economic and social principles by which it may sustain its life, technological developments will languish for lack of a favorable environment for growth. Although predominately technological in its viewpoint in its early history, the A.S.M.E. has an extensive record of achievement to its credit in these other fields. Because of this tradition, its members are likely to be sensitive to the need of the times, and to welcome such stimulating papers as this month's issue provides.

A Survey of the Profession

FROM the American Engineering Council there has been received too late for extensive quotation in this issue a news letter devoted to the proposed survey of the engineering profession to be undertaken by the United States Department of Labor under the direction of Dr. Isador Lubin, Commissioner of Labor Statistics.

This will be the most comprehensive nation-wide survey ever made of a professional group. Its results are expected to be of immediate practical application to the engineering employment program, and will serve to indicate in what fields the concentration of engineers is greatest and in which there is room and need for men.

The survey will be conducted under the guidance of the American Engineering Council. Engineers are to be asked to give unsigned confidential answers to a questionnaire to be sent to some 100,000 individuals. If you receive such a questionnaire it is of the utmost importance that you fill it out promptly, accurately, and completely, so that the benefits from the statistics gathered may be made available without delay.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

APPLIED MECHANICS

New Applications of Pendulums to Engineering Problems

THE author starts with a brief history of the pendulum and proceeds to enumerate some of the new applications of this device. Among these is a study of friction and properties of lubricants. In these matter two experimental methods were used. The first observation was made of the decrease of oscillations of a pendulum having a steel roller, and oscillating in a journal of the metal being studied. If $\Delta\theta$ is the average decrease observed per period, h the distance of gravity from the axis, and r the radius of the cylinder, the coefficient of friction is given by $f = \frac{h\Delta\theta}{4r}$. This formula was checked by experiment and it was found that the oscillations decrease in arithmetical progression and that this decrease is independent of the weight of the pendulum. The values of f are irregular in tests with dry parts. The use of a lubricant indicates that the friction, quite large at the start, decreases as a function of time tending toward a constant and well-defined limit which incidentally rises with the increase of speed. The addition of a small quantity of colloidal graphite reduces the friction by about 10 per cent but at a high temperature of the order of 200 or 300 C, particularly where the load is great, the graphitic oils lose part of their lubricity.

The other method used consisted in measuring the static deviation of a pendulum in a journal of the metal studied brought about by the rapid rotation of a steel axle inside of the journal. The two methods have given concordant results.

The application of the pendulum to the measurement of air resistance is discussed next. Here again the small forces exerted on the pendulum are measured by observing the decrease in its amplitude. The body whose aerodynamic resistance is to be measured is attached to a pendulum rod from 1.50 to 10 m long. The damping of the oscillations is observed by the Poggendorff optical method and the resistance of the air is deduced therefrom by means of a simple formula. These experiments have shown that the average resistance R of air is of the form

$$R = a\rho\, SV^2 + bS^{4/3}\gamma$$

where R is the resistance, ρ the density of the air, S the surface of the main couple of the body, the resistance of which is measured, V its velocity, γ its acceleration, and a and b are constants. This method, which proved to be extremely sensitive, makes it possible to measure the effect of factors, the influence of which on the resistance of the air is as yet little known. Among these factors are the presence of walls, orifices in the body, the resistance of which is measured, variations of pressure and temperature of air, etc.

The original paper presents a very extensive discussion of measurement of hardness by means of a pendulum. This cannot be abstracted because of lack of space. Among other things, the author discusses the relation between the pendulum hardness number and the Brinell number. The matter is of importance as the relation between the two is not absolute.

The pendulum can also be used for investigating the elastic properties of mechanical systems. This leads the author to apply the method of coupled pendulums to measuring the modulus of elasticity of materials.

This method has been applied to the measurement of the modulus of elasticity of cast-iron bars. An example of the application of the process to aluminum bars is cited. The value obtained by the pendulum method was 7650 kg per sq mm which compared with 7600 kg per sq mm obtained by the Martens extensometer. On cast-iron test bars of very variable quality, the moduli were found to vary from 6000 kg to 16,000 kg per sq mm. This cannot be compared with extensometer readings because of the character of the curves of the latter. Among the advantages of the method is cited the fact that the bar is subjected to very small alternating stresses, so that the effect of hysteresis need not be considered. Moreover, the method does not require very delicate handling. Fig. 10 in the original article shows a pendular elasticimeter for measuring the Young modulus of a rectangular section test bar. (Prof. Paul Le Rolland, Faculty of Sciences at Rennes, in *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. 133, May, 1934, pp. 317–344, and discussion pp. 345–347, 10 figs., in the original article, *eA*)

AERONAUTICS

Silent Flight of Owls

THE author, whose previous paper was abstracted in MECHANICAL ENGINEERING, Vol. 55, No. 7, July, 1933, pp. 440–441, has been trying to trace in the flying equipment of birds versions of many of the refinements encountered in modern airplanes with an eye to possible future developments.

The peculiarities of the feathers which make silent flight possible for an owl are the leading-edge comb, the trailing-edge fringe, and the downy upper surface. The owl needs silent flight, because of its hunting methods, which require it to cruise at a low altitude without being heard by its prey. That the three characteristics of the English owl's wings referred to are real silencing devices is shown by the feathers of the fish owl of tropical Asia. Its special prey, being submerged, is unable to hear the noise of its wings and this particular kind of owl has normal unmodified feathers which give it a higher aerodynamic efficiency than the feathers of the silent-flight owl.

The part of the paper dealing with the effect of the comb on the owl's feather as a silencing device is of particular interest. This comb is a remarkably stiff fringe on the front margin of every feather that functions as a leading edge. The teeth of this comb are extensions of the barbs or fibers that form the front web of the feather.

The noise produced by an airfoil is said to come from the region in rear of the leading edge of the suction surface where there is a sudden fall in air pressure. This noise is, perhaps, augmented by sounds emanating from the region in the rear of the trailing edge where the lower air stream at high pressure mixes with the upper stream, which is not only rarified, but is traveling at higher speed. There may also be sounds produced through oscillations of the trailing edge.

The comb, in a barn owl's wing, is so placed that the air stream which is destined to become the boundary layer flowing over the wing must pass up through it before reaching the true leading edge. The most obvious effect will be a reduction in the speed of this air by the time it reaches the leading edge. It is conceivable that this has a silencing effect by reducing the suddenness of the fall in pressure in the boundary layer.

There are two additional effects. Careful scrutiny with a magnifying glass discloses the fact that each tooth of the comb juts out with a slight upward inclination from the leading edge, and is also inclined toward the top of the wing at an angle of about 45 deg; further, that each tooth is really a blade, set at much the same angle of incidence as the slat of a Handley Page slot in the open position. This means that the boundary layer, on arrival at the true leading edge, will have been given momentary wash-out, and will have been deflected so as to flow more closely over the upper surface of the wing than it does in normal feathers.

The wash-out may well have a silencing effect, for an airstream striking the leading edge of a wing at an angle other than the normal should produce proportionately less noise.

The down-wash resulting from the slow effect possibly reduces noise by raising the pressure immediately in rear of the leading edge.

Support is given to these theories by the variation in development of the comb in different parts of the span of the wing. The teeth are longest in the middle of the wing, diminish outward and inward along the span, and are entirely absent at the top and root of the wing. In the mid-wing, the teeth have bristle-like extensions, normal to the leading edge, which must greatly increase the braking effect on the air flow. The comb, then, is apparently designed to have the greatest effect in those parts of the wing where the incidence in the down or power stroke of flapping flight is thought to be greatest. There can be little doubt that the greater the incidence, the more tendency there is for sound to be produced. The reason for the presumed variation in incidence itself is that the root of the wing has but little downward movement, while the tip is sufficiently flexible to give to the pressure of the air and be twisted rear edge up in the air stream that it encounters.

The theory that wash-out has a silencing effect is given additional support by the absence of comb at the wing tip, for here the air is already washed out, owing to the feathers being bent upward as well as outward by the reaction of the air they displace. This distortion of the wing tip is shown clearly in many photographs.

The following conclusions are arrived at:

There are two characteristics of the flight of owls that militate against the possibility that their silencing modifications might be adapted to airscrews. First, there is the wing loading, which is lighter than in any other group. It is, however, only a little lighter than in eagles and the like, and these are notoriously noisy in flight. It would seem, then, that although the light loading of an owl may assist silencing by permitting a slow flap and small angles of incidence, its main purpose is to permit the bird, without difficulty, to carry the extra weight of its victims. Second, there is the low speed of the wings, which is in no way comparable with that of airscrew blades. Unfortunately there are no birds with high-speed wings, such as the partridge, that require silent flight, but it is not impossible that without creating excessive drag, modifications of sorts would be as effective at high speeds as at low. They would, at least, have more decibels on which to make a start. (Lt.-Commdr. R. R. Graham, R. N., *The Journal of the Royal Aeronautical Society*, vol. 38, no. 286, October, 1934, pp. 837–843, *tpA*)

ENGINEERING MATERIALS

Pliofilm

THIS is a material intended to perform most of the functions of cellophane. It is derived not from cellulose but from rubber. It is said that it is capable of retaining its moisture-proofness on wrinkling and creasing. It is not greatly affected by changes in the humidity of the atmosphere. It does not have the stretchable elasticity of rubber and its weight is such that more than 20 per cent extra area per pound is provided compared with the usual cellulose type of transparent material. It can be heat-sealed for which purpose only moderate heat and pressure are required. The material has been introduced by the Goodyear Tire and Rubber Co. (*Industrial Bulletin of Arthur D. Little, Inc.*, no. 94, October, 1934, p. 1, *d*)

Nitricastiron

NITRICASTIRON is the trade name given to several varieties of cast iron containing aluminum and capable of case-hardening by certain nitrogen-containing materials, such as ammonia. To obtain the proper hardness the material has to undergo certain heat treatments. The true hardness of the nitrided case on nitricastiron is difficult to obtain. The articles increase slightly in size on nitriding, but the amount of growth is quite constant under the same conditions so that after it has once been determined for a given material or article it can be allowed for in the final machining or grinding, or it can be removed by lapping or careful grinding of the nitrided part. An increase in diameter of 0.002 in. in a specimen having a case depth of 0.030 in. serves as a fair example of the extent of this growth in nitralloy. The material is claimed to have a high wear resistance, figures being given in the original article, and resistance against certain forms of corrosion. The original article describes experiments on various processes of casting this material. (V. O. Homerberg, Associate Professor, Mass. Inst. of Technology, and D. L. Edlund, Mass. Inst. of Technology, in *Metals and Alloys*, vol. 5, no. 7, July, 1934, pp. 141–144, *d*)

Corrosion Troubles With Stainless Steel

CONTRARY to the popular impression, stainless steel is subject to rusting under certain conditions. The author divides all of the stainless steels into several groups depending upon the purpose for which they are used and the heat treatment to which they are subjected. The mechanism of corrosion has not yet been fully explained, but it does appear that a metal which is capable of producing a stable, continuous, adherent, and insoluble oxide film will not readily corrode, and therefore any conditions existing in the metal which tend to prevent the formation of such a film are to be avoided. The conditions usually encountered that affect stable film formation are impurities in the metal, physical differences, thermal treatment, and composition. (The last need not be considered in the case of high-quality steels.)

Impurities in the sense considered here refer to surface inclusions produced by the mechanical operations to which the steel has been subjected during the rolling or drawing processes. For example, the rod or sheet may not have been completely descaled before a subsequent rolling or drawing and particles of mill scale may have become rolled into the surface. In such a case corrosion proceeds at the expense of the base metal. Similar action occurs when the metal has a rough surface, due to pits or surface defects, and is then rolled or drawn to the required size. The indentations are not clean. Generally.

traces of oxide or scale are present, and during the process of reduction of the rod, wire, or sheet, metal flows over the pit or indent forming what may be likened to a sliver. If the material is then ground or polished it is almost impossible to detect these tiny flaws. Rusting will proceed, however, at these points, and if the flawed metal be very thin in section, particles may fall out and give a badly pitted surface to the material.

Internal stresses in the steel when subsequently released by heat treatment or machining may cause distortion through adjusting themselves to a state of equilibrium by removal of the outer skin. In machining, the heavier the cut and the coarser the feed, the greater is the stress created in the surface of the work; and the harder or tougher the steel, the greater is the effort required and the greater the degree of stress promoted in the machined surface. Stainless steels are not easy to machine, and apart from other considerations these steels should be machined with fine finishing cuts.

When material is in a state of unequal strain a difference of potential is produced, and selective corrosion, under favorable conditions, takes place. The strained material, being electropositive to the undistorted material, produces a galvanic couple in the presence of an electrolyte, and hence corrosion takes place. It therefore follows that finishing cuts should be as light as possible to render the possibility of strained surface material being present a remote one. For this reason it is customary to specify a polished surface for stainless-steel articles as this can only be produced by light grinding and polishing, avoiding to a great extent the possibility of differential strain in the surface layers of the article.

Defects in stainless steels that promote localized corrosion troubles are seldom detectable by visual examination and must be investigated by some such method as a salt-spray test. It is pointed out that surface conditions may not always be so severe as to warrant subjecting the material to the salt-spray test. Under these circumstances the humidity test described in the original article forms a useful means of testing these steels. Two tables in the original article give, first, exposure-test results on stainless steels with various natures of surface and, second, comparative-humidity tests on a steel containing 1 per cent nickel and 12 per cent chromium. (P. Mabb in *Mechanical World and Engineering Record*, vol. 96, no. 2483, Aug. 3, 1934, pp. 95–98, 1 fig., *pe*)

FUELS AND FIRING

Pulverized-Coal Installation at Grimethorpe Colliery, Great Britain

ONLY certain features of this interesting article can be abstracted here.

A novel feature is provided in this plant in the form of bin-level indicators which register when the level of the fuel rises above or falls below a certain point. The supply of pulverized coal is controlled from a central indicating panel situated in the boiler house adjacent to the pulverized-coal preparation plant. This indicator shows when the main pulverized-coal storage bin is empty or full, and thus enables the operator to start up or shut down the pulverizing plant accordingly. It also shows when any of the pulverized-coal storage bins in the boiler house require replenishing, and also when all bins are full and the conveyer has been cut out. Indicators are also fitted to the 50-ton raw-coal bunker for registering when the bunker is full or empty. By this means the fuel supply and preparation can be controlled by a single operator.

For a colliery boiler plant water-tube boilers have certain disadvantages, so that the problem of the successful utilization of coal dust in collieries largely depends upon the success of the application of pulverized-fuel firing in Lancashire boilers.

In the Grimethorpe plant the entire steam requirements are supplied from pulverized-fuel-fired Lancashire boilers.

Early attempts made to apply pulverized fuel to the shell-type boiler adopted the direct-firing methods used in the water-tube boiler, and therefore involved lining the furnace flues with refractory brickwork to enable combustion to be maintained. These attempts consequently were invariably attended with those serious disadvantages always present with any system of firing necessitating an internal lining of the flues with refractories.

At the high rate of heat liberation required in this type of boiler and the high resulting temperatures, firebrick linings inside the furnace flues are bound to produce continual slagging of the ash if good combustion is to be maintained. Such slagging leads to frequent brickwork renewals, as the slagged ash adheres to the brickwork, causing rapid deterioration of its surfaces, and is, moreover, most difficult to remove efficiently from the furnace.

Where attempts have been made to reduce the temperature of combustion, in the hope of increasing the life of refractories, experience has shown that this has always resulted in high carbon losses in the ash, due to incomplete combustion, with the resultant reduction in boiler output and efficiency.

Apart from the defects noted, it is, from an engineering point of view, fundamentally wrong in principle that any part of the boiler flues should be permanently covered with brickwork, thereby preventing the proper inspection and examination of the furnaces and the discovery of defects or leakages. Moreover, brickwork lining in the furnace flues insulates valuable heating surface from the radiant heat of the flame, which would otherwise be available for heat transmission to the water in the boiler.

By the system of pregasification, the powdered coal is subjected to a preliminary process of gasification by partial combustion in a relatively small chamber, prior to entering the main furnace flue of the boiler. The combustible gaseous-products so formed are then admitted to the boiler flue, together with the requisite secondary air for their final complete combustion.

The action of this process may be termed a two-stage combustion of the coal. It is similar to the reaction in the ordinary gas producer, with, however, the important difference that there is no cooling of the gaseous products and consequent loss of sensible heat. In this case the pregasifying chamber communicates directly with the boiler flue, so that the combustible gaseous products which are formed pass to the boiler flue itself, where they become mixed with the secondary air necessary for complete combustion.

The conditions in the pregasifying chamber are comparable with those in a producer, and are not those of an ordinary combustion chamber. The quantity of air supplied with the fuel, as it enters the pregasifying chamber, is definitely limited to the amount required for gasification, and no more. As complete combustion is not developed until the fuel and gases have left the pregasifying chamber and entered the furnace flue, the temperature in this chamber does not exceed a predetermined figure, and brick of an ordinary quality, therefore, gives very long service.

Fig. 1 shows the construction of the G.P.F. burner. The primary air and coal stream enters at the fuel inlet pipe which leads into the small separating chamber. This chamber performs the function of a small cyclone separator, and since fuel particles have more density than air, the rapid change of direc-

tion of the fuel and air stream causes the coarser particles to be thrown to the outer side of the chamber and to the base of the screw-threaded ribs with which the chamber is lined.

The "rich" portion of the stream passes through the inner annular passage, the amount of air passing out being limited and controlled by the area of the annular passage formed by the cone. The screwed ribs of the separating chamber served to distribute the "rich" coal stream, containing the coarser particles, equally around the exit annulus, so that a uniform circumferential distribution of fuel is obtained.

By the longitudinal adjustment of the cone, which may be carried out while the burner is in operation, the "richness" of the mixture issuing from the inner annulus can be set to the proportions desired. The remainder of the air and the fine dust unaffected by the centrifugal effect takes a backward path through the ports and passes around the outer side of the separating chamber to the outer annulus.

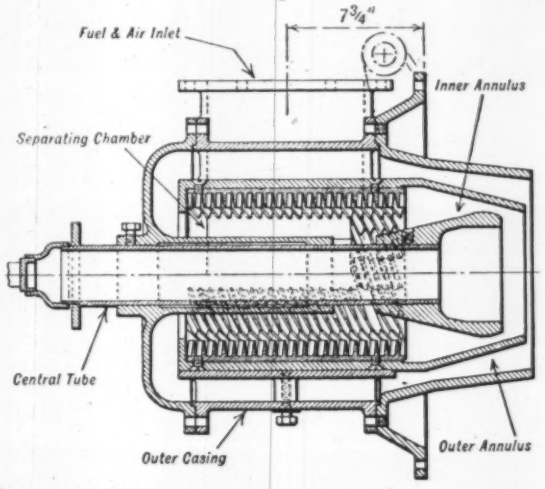


FIG. 1 G.P.F. PULVERIZED-COAL BURNER FOR LANCASHIRE BOILERS

The outer stream is therefore composed of a "weak" mixture of fine dust, while the inner stream is a "rich" mixture of coarse particles; and, as previously explained, the rate of flame propagation of these two separate streams is considerably lower than would be the case were they introduced as one stream. The inner and outer annuli are designed so that the two streams, on emerging from the burner, do not start to mix until a few inches beyond the burner orifice. No oxidation of the burner nose, therefore, takes place, but, in fact, the opaque powdered-fuel stream itself is made use of in this design of burner to protect the metal of which it is made from the intense radiant heat of the flame.

On entering the combustion chamber the fine particles, which are on the outside of the stream, become immediately ignited and assist in the combustion of the coarser particles in the center. Air is introduced to the center of the fuel stream through the inner tube, which provides the requisite oxygen to enable the coarser particles of fuel to start immediate ignition.

Owing to the comparatively low speed of the fuel stream issuing from this burner, the particles of fuel and ash have less momentum and are not thrown out of the flame by the centrifugal action as with the usual rotary type of burner. In consequence, the unburned carbon in the ash is a negligible quantity and the chamber walls are not sprayed with molten ash. (*The Engineer*, vol. 158, no. 4107, Sept. 28, 1934, pp. 319–320, 4 figs., *dA*)

INTERNAL-COMBUSTION ENGINES

Detonation in Diesel Engines

THIS is part of a general article dealing with the processes of combustion in high-speed internal-combustion engines, both carbureter and Diesel type. The author states that according to the more recent investigations the cause of detonation has to be sought for in the delay in the combustion of the fuel injected. To burn this fuel requires a certain amount of time and during this time a larger amount of fuel may be injected than can burn with sufficient speed without detonation, and this produces pinking. The pressures under conditions of detonation are extremely high and may reach the magnitude of 100 atm in cases where the injection has been started very early.

To eliminate this detonation in Diesel engines, it is necessary to reduce to the minimum the delay in ignition of the fuel. One of the ways of obtaining it is by atomizing the fuel as finely as possible. This brings a more rapid combustion because of increased concentration of oxygen about the particles of fuel. There are also persons who believe that in the Diesel engine, as well as in the carbureter type of engine, the fuel must be vaporized prior to combustion, this being facilitated also by finer atomization. Another method is to induce higher compression. Contrary to what happens in carbureter-type motors, an increase in compression materially reduces detonation noise, due to the fact that delay in ignition is reduced and the higher air temperatures in the cylinder counteract the effect of cooling at the time of injection. Many working cycles employing auxiliary chambers have been developed in order to modify the timing of the combustion of the fuel and reduce the rise of pressure produced by detonation.

All of these auxiliary chamber processes are developed with the aim of initiating combustion in a chamber under conditions

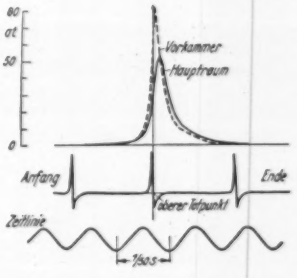


Fig. 2

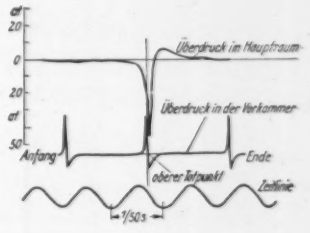


Fig. 3

FIG. 2 PRESSURE VARIATION IN THE PRECOMBUSTION CHAMBER AND MAIN COMBUSTION CHAMBER OF A DIESEL ENGINE

FIG. 3 DIFFERENTIAL PRESSURES BETWEEN PRECOMBUSTION CHAMBER AND MAIN CHAMBER

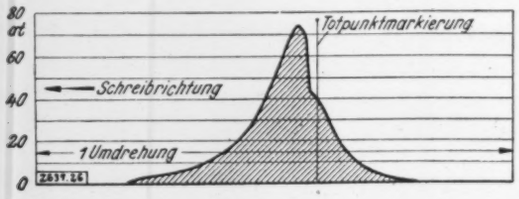
(*Vorkammer* = precombustion chamber; *Hauptraum* = main chamber; *Anfang* = beginning; *Ende* = end; *oberer Totpunkt* = upper dead center; *Zeitlinie* = time curve; *Uberdruck im Hauptraum* = gage pressure in the main combustion chamber; *Uberdruck in der Vorkammer* = gage pressure in the precombustion chamber.)

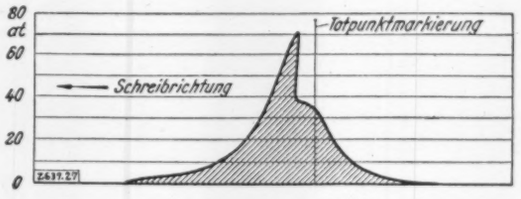
of deficiency of air, and keeping away from the main engine structure the high peak pressures.

In the precombustion-chamber process the fuel is injected into a chamber, ignited there, and then blown into the main cylinder. From indicator diagrams obtained with a quartz indicator at the Institute of Research on Power Locomotion, Stuttgart, it would appear that the desirable action of the precombustion chamber is clearly recognizable at high speeds. In these tests the curves shown in Figs. 2 and 3 have been ob-

tained, the former from the main chamber of the motor and the other showing the variation of the differential pressure between the precombustion chamber and the main chamber of the motor. In Fig. 2 the precombustion-chamber pressure amounts to as high as 85 atm while the pressure in the main chamber decreases with increase in revolutions. In both of these figures, n = 1890 rpm; N_e = 77.0 hp; injection pressure, 95 atm; the injection point about 15 deg ahead of the upper dead center. A set of curves in the original article, Figs. 24 and 25, shows an interesting distortion of the curves in the case of very late injection.

Another process is the so-called air-storage process, in which a substantial part of the fuel is injected into the main chamber, while the air collected in the air storage is used for purposes of slow combustion and for blowing the flame into the main chamber.





FIGS. 4 AND 5 PRESSURE VARIATION IN A JUNKERS DOUBLE-PISTON DIESEL ENGINE WITH DIFFERENT FUELS

Fig. 4 (left) pressure variation at n = 970 rpm; Fig. 5 (right) pressure variation at n = 660 rpm and a fuel different from that in Fig. 4 (*Schreibrichtung* = direction of recording; *Umdrehung* = one revolution; *Totpunktmarkierung* = dead center notation.)

The matter of fuel has therefore a dominating influence on the performance of a Diesel motor, as proved by Figs. 4 and 5 in the original article showing tests carried out with different kinds of oil. (W. Kamm and Paul Rickert in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 78, no. 28, July 14, 1934, pp. 851–855, 27 figs., *eA*)

LUBRICATION

Cleaning and Reclaiming Axle-Box Oil and Packing

THIS system is used on the Jhansi Division of the Great Indian Peninsular Railway for combating the hot-box evil. The apparatus consists of two parts—the oil-extracting plant and the oil-refining plant. In the first, substantially, the waste packing reclaimed from axle boxes is placed in an inner perforated drum driven by a steam turbine. A steam jet is fitted to an outer drum. The steam is admitted to the perforated drum where it strikes the turbine blade and rotates the drum.

The rotating action at high speed extracts the oil from the waste. The oil-refining installation consists of a battery of one or more cylindrical tanks about 2 ft 5 in. high by 2 ft 1 in. in diameter with a coiled steam pipe. The oil is brought to the boiling point by contact with the coils and is boiled for two hours at a temperature which should not exceed 212 F. After boiling, this mixture is allowed to settle for 24 hr and the top layer of clean oil is drawn off by means of a steam-driven rotary pump into a second boiler of similar dimensions while the residue is drained off. In the next boiler the oil is boiled without water for a period of 3 hr at a temperature which is carefully kept below 212 F. After this boiling process the oil is allowed to settle for 36 hr and is then pumped out into storage tanks.

A centralized system of cleaning the oil and reconditioning the packing is used. (*The Railway Gazette*, vol. 61, no. 7, Aug. 17, 1934, pp. 271–272, 2 figs., *d*)

MACHINE PARTS

High-Speed Belt Drives

THIS is a theoretical and experimental investigation of the performance of modern rubberized belts.

High-speed belt drives have either very small pulleys or very high belt speeds. In the former case it is of importance to ascertain the influence of stiffness on contact angle and idling loss; in the latter a critical scrutiny of the influence of centrifugal force is called for. A theory of centrifugal force, originated in Germany, shows that the theory current in America is merely an approximation, which, under certain circumstances, seriously overestimates the influence of centrifugal force on shaft pull. Particularly important is the fact that this is true when the belt is slack and the speed is high. Considerable American experience supports this conclusion.

In this study the German formula is rederived and expanded to cover influence of belt stiffness and varying shaft distance. Also, a formula is derived for the influence of stiffness on contact angle. Both the centrifugal-force formula and the stiffness formula are checked experimentally.

Tests on idling losses show these to be comparatively more serious for V-belts than for flat cord belts. On small pulleys, particularly at reduced load, the idling losses may result in a comparatively low efficiency for V-belts. These can be run quite slack, however, while the flat cord belts must be run very tight to transmit a power commensurate with their cord strength.

An effort is made to draw conclusions from the relations of theoretical creep and measured creep as to the effectiveness of the arrangement of the cord section. A rather clear relation seems to exist. On the other hand, the relation between cord section arrangement and life is not so clearly established. It is evident that in this respect the arrangement of the cord section is not the only influence.

Particular attention was paid to the action of centrifugal forces. Among other things, it is pointed out that when belts are very slack the influence of the centrifugal force on adhesion may be very much less than is commonly assumed. This may be a partial explanation of the astonishing degree of slackness with which automobile fan belts may be run.

Even the German investigations, however, do not deal with certain important phases of this problem. They consider the influence of sag on centrifugal force but do not go into the influence of flexibility which with certain modern belts is important. German writers have also pointed out that in addition to what happens when the belt passes over the pulley there is a centrifugal force from the belt also between the pulleys and this centrifugal force sets up a tension equal to and oppositely directed from that set up on the pulley. It is because of the fact that the belt stretches that the ordinary formula for centrifugal force and for tension in the belt cannot be used and the new formulas derived by the author had to be

developed. Attention is also called to the following passage in the original paper.

It is usually believed that the transmissible horsepower rapidly decreases when the belt speed exceeds 4000 or 5000 ft per min. Nevertheless, an experimental drive at the Technological Institute of Charlottenburg, Germany, transmitted a great deal of power at speeds up to 12,000 ft per min. Computing rope drives on the assumption that the transmissive power is reduced almost directly as the slack-side tension is reduced by wv^2/g, a maximum horsepower for manila rope is usually computed at 5000 ft per min. Yet, a very well-known British rope expert, Edward Kenyon, writing in *Engineering*, 1909, p. 368, assumes in his standard horsepower tables for cotton ropes a steady increase in horsepower up to 7000 ft per min and even beyond. (Investigation by C. A. Norman, based on tests by C. A. Hempstead, Ohio State University Studies, Engineering Series, vol. 3, no. 2, May, 1934, also listed as Engineering Experiment Station Bulletin No. 83, 31 pp., 27 figs., *et*)

MACHINE-SHOP PRACTISE

Dural Riveting

DURAL rivets are generally made in heading machines embodying a one-piece heading die; hence, the original size of the rivet wire is slightly below nominal and the rivet itself is slightly tapered under the heading. The mechanism of riveting is such that with the filled hole the surrounding sheet is subject to radial pressure, the local intensity of which is somewhat proportional to the local rigidity of the sheet, and if the rigidity of the sheet is locally uniform, so is the deflection.

The type of head form has an influence on the degree of shank swelling and the location of its maximum amount. In the case of flat-headed rivets, the flat snap imposes simple frictional restraint on the rivet shank end while the button or mushroom head had an added geometrical restraint. Consequently, the swelling of the shank is usually exaggerated near the surface of the sheet next the flat head being squeeze formed and slightly nearer the original head when the new head being formed is of button or mushroom type. Thus, the bursting pressure on the sheet is not only non-uniform around the circumference of the rivet shank but is also non-uniform along the length of the shank in the sheet. Hence there is a tendency of the sheet to curl. Individually, all these deformations are of negligible magnitude. It is when their effect is cumulative as in a long row of rivets in a fairly narrow component that they begin to assume importance.

The physical conditions usually forgotten are that the resistance of dural to plastic flow in rivet heading is, at room temperatures, about equal to that of steel, while the modulus of elasticity of the dural sheets being riveted is only about a third that of steel. The rivet heads are finish-formed plastically in compression, while the sheet is stretched elastically in compression and hoop tension.

The author discusses next the air-cylinder sizes and suggests the advantage under certain conditions of fitting of thin hard sleeves in the customary soft aluminum cylinders and substituting automotive-type piston rings for the cup-leather packing. A formula for the effective closing force is given.

He also mentions that the practise of usual linkages of the toggle type to avoid the use of high-supply pressure is safe *only* when the arcuate motion is limited through the squeezing range and the use of a given linkage is limited to one diameter of rivet, length of shank, shape of head, and thickness of components being secured. Certain faults in rivets are discussed. (Roland V. Hutchinson in *American Machinist*, vol. 78, no. 19, Sept. 12, 1934, pp. 638–639, *p*)

METALLURGY

Shorterizing Carbon Steels

IT IS claimed that by this process steel may be obtained with a hardened surface gradually merging through the changed zones to a soft core. It is said that the Brinell hardness of the steel in its unhardened condition was 235 and after treatment 590. The article contains some photomicrographs of the treated material but no information as to the nature of the process itself. (*Mechanical World and Engineering Record*, vol. 96, no. 2483, Aug. 3, 1934, p. 99, illustrated, *d*)

NOISE

Reduction of Exhaust Noise of Motor-Cycles

THE author refers to a previous report published in German by Schmidt and Kauffmann describing the work done upon the exhaust noise of six- and eight-cylinder automobile engines. This showed, among other things, that the noise is divided into two parts—one including frequencies ranging from 50 to 400 per sec and followed by a zone of remarkably little noise; and the other extending from 3000 to 10,000 per sec. The higher frequencies produce a greater proportional effect upon the ear.

The present investigation was started with a discussion with motor-cycle manufacturers at Coventry, England, from which it became evident that the length of the pipe which connects the engine with the muffler is so intimately involved in the design of the engine that any alteration of this pipe would be very far-reaching in its effect. It was therefore agreed that modifications should be limited to the muffler beyond the end of the pipe. Tests made with various types of mufflers have led to the conclusion that the high-pitch zone was by far the most offensive. The type of muffler most effective in reducing this high-pitch part was one based upon the absorption principle. The details of the tests are presented in the original article.

Among other things the tests indicated that the detrimental effect of high exhaust pressure lay not in an increase of back pressure on the piston during the exhaust stroke but in increasing the amount of exhaust gas remaining in the cylinder and thereby decreasing the amount of charge drawn in for each cycle. In this matter the important factor is the instantaneous pressure in the exhaust pipe when the exhaust valve closes, rather than the mean pressure in the exhaust pipe. Other tests indicated that the size of the muffler should be in direct proportion to the diameter of the exhaust passage through the silencer.

The absorption-type muffler involves the use of a material such as that known as glass silk. This has proved quite satisfactory in an enormous number of mufflers used on motor cars and large motor vehicles. There may be some doubt whether this material when exposed to the much more violent vibration of a motor-cycle and the much greater quantity of oil which passes out through the exhaust (especially the exhaust of machines of the two-stroke type) would remain satisfactorily effective. The exact function of this absorbent material has not been very clearly explained, but the author assumes that its action depends upon delaying the return of gas into the exhaust duct until the crest of the sound or pressure wave has passed and in protecting the external surface of the silencer from the shock of these waves. In this action the capacity of the space filled loosely with packing appeared to be important.

It may therefore be considered whether it might not be possible to adopt some form of perforated tube which would give the right degree of resistance to the passage of peak pressures, and thereby produce the necessary delay in their return.

For this purpose it appeared preferable to use a form of perforation which should give less resistance to passage outward than to return flow in the opposite direction. The holes, therefore, should be not plain punched or drilled holes, but lipped holes formed by stabbing. For flow from one side a streamline orifice is formed, but to flow in the opposite direction an orifice of a large coefficient of contraction is presented. This type of material is used in nutmeg graters and, on a large scale, in potato-cleaning machines. It can be obtained for about the same price as perforated sheet.

Mufflers composed of tubes of this material instead of normal perforated sheet were made and tried with no soft packing whatever. The noise was slightly greater than with the packed muffler. Experiments made with the four-stroke cycle machine showed that an air intake muffler gave important improvement. The matter of patents was given very careful consideration, no patents having been applied for the new features. (Paper by Wing Commander T. R. Cave-Brown-Cave, read before Section G of the British Association, at Aberdeen, Monday, Sept. 10, 1934, abstracted through *Engineering*, vol. 138, no. 3584, Sept. 21, 1934, pp. 316–318, illustrated, *e*)

POWER GENERATION

Claude-Boucheron Floating Ice Factory

GEORGES CLAUDE, whose work on generation of power from sea water attracted extensive attention some time ago, has now purchased a tramp steamer, *Tunisie*, and fitted her out with a complete equipment of evaporators, turbines, condensers, and ice-making plant.

The principle on which the plant of the *Tunisie* will work may be readily understood from an inspection of Fig. 6. Within a closed vessel there is a central bulkhead containing a low-pressure turbine. To the left of this bulkhead there is an evaporator *C*, which receives water at a temperature of 25 to 28 C taken from a depth of 2.5 m; to the right, a condenser *D* is supplied with water at 2 to 3 C drawn from a depth of 650 m. A suitable air pump *G* is connected with the spaces on both sides of the bulkhead. The turbine shaft drives at one end an alternator *A*, and at the other an ammonia compressor *B*. The action is obvious. The relatively warm water boils under the reduced pressure, and the vapor from it passes through the turbine to the condenser. The condensate mixes with the overflow of warm water and returns to the sea through the pipe *H*.

So much for the principle. It is realized on the *Tunisie* in the form shown in the illustrations, and particularly by Figs. 4, 5, and 6 in the original article. From Fig. 5 it will be observed that the main vessel is divided by eight bulkheads, in each of which there is a single-stage turbine. At one end there are mixing or jet condensers, and at the other, surface condensers. This difference was made solely with the object of ascertaining the respective merits of the two types. The openings through the bulkheads are 2.5 m in diameter and it is estimated that each turbine will develop 275 kw on a temperature difference of 22 C. The alternator is rated at 800 kw and the rotary ammonia compressor will consume 1300 kw. In full operation the consumption of warm water should be 6 cu m per sec, and of cold water 5 cu m per sec. The cold- and warm-water tubes are 2.5 m in diameter.

Particular interest attaches to the long tube which descends nearly to the bottom of the sea. When completed it will be between 650 and 700 m long, and it is 2.5 m diameter. It is made of quite thin plates, 3 to 3.5 mm in thickness, autogenously welded, and covered for insulation purposes with a layer of wood. A block, 200 tons in weight, will anchor the lower end of the tube, while its summit will be supported by a spherical float, 9 m in diameter, made of steel, 14 mm thick,

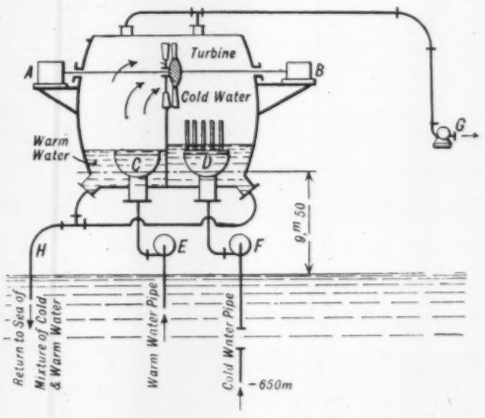


FIG. 6 GENERAL SCHEME OF THE CLAUDE-BOUCHERON FLOATING ICE FACTORY

electrically welded. An opening near the bow of the *Tunisie* has been provided to enable the tube to be assembled in lengths of 6 m, which, after bolting together, will be lowered stage by stage. (*The Engineer*, vol. 158, no. 4108, Oct. 5, 1934, p. 345, 6 figs., *d*)

POWER-PLANT ENGINEERING

Automatic Gas-Fired Boiler for Ford Exhibition Building

GAS was selected as the fuel to operate this plant at the Century of Progress Exposition in Chicago because of its cleanliness and ability to respond quickly to wide variations in steam demand. The boiler is of the horizontal fire-tube type with a nominal rating of 80 hp and with 1813 sq ft of heating surface. Steam is maintained at 150 lb pressure, a special control system being provided on the gas burner to maintain the steam pressure uniformly. The primary controller is a "pressure-stat" built along the principle of a Wheatstone bridge which, through a reciprocating damper motor, coordinates the stack-damper setting with a motor-operated gas valve in the gas supply line to maintain the correct steam pressure with an unvarying air-gas ratio. This control system will come to rest at any point when the control balance point between steam pressure and fuel flow is attained. (This varies from the ordinary method of high-low control which has but two fuel-flow settings, one high and one low, and alternates between them.)

The advantages are twofold; first, it prevents overshooting and undershooting of the required steam pressure; second, it provides greater economy of fuel consumption by eliminating sudden changes in the rate of firing. An additional "pressure-stat" cuts off the fuel supply entirely in case of excess steam pressure (above a 5-lb margin). A low-water safety shuts off the gas fuel flow in case the water level drops below a predetermined point.

The means to provide safe ignition and operating period are described in the original article, a thermionic-tube control system being used. In this system, an electrode is mounted so

that it extends into the flame of the main burner. The flame completes the electrical circuit of a grid-glow-tube relay system. The circuit is so arranged that when an electrical path is completed from the electrode to ground, the relay closes its contacts. When this electrical path is interrupted, the relay opens its contacts. The use of a modulating control system of this type in which the stack-damper setting is coordinated with the opening of a gas valve is, of course, predicated on constant gas pressure ahead of the control system and constant breaching draft on the stack side of the damper. A gas governor takes care of the former and a barometric draft regulator at the stack provides the necessary constant draft. In this way the air-gas ratio of the combustion efficiency remains practically constant throughout the full range of boiler output. (*Power Plant Engineering*, vol. 38, no. 9, September, 1934, pp. 427–428, 2 figs., *d*)

Fly Ash for Cleaning Turbine Blades

MANY methods of cleaning turbine blades have been tried out at Cahokia Station and it appears that fly ash from the combustion of pulverized coal has the proper characteristics of fineness, cheapness, and abrasiveness for this purpose when used with compressed air through a regular gunite machine. Fly ash is exceedingly fine and handles readily in the blower. The particles, while reasonably hard, are not as sharp as sand, being well rounded in the burning process. Unlimited quantities of it are available at practically no cost.

Fly ash was tried in a gunite blower using compressed air to clean the turbine rotor of a 50,000-kw turbine. The results were very satisfactory. Only two men were required to do the entire job and it took about one-half the time normally required for scraping. To check whether the ash was wearing away the metal a spare blade was weighed on a laboratory balance before and after cleaning. Calculations show that less than 0.0005 of an inch of metal was worn away. (*Union Electric Magazine*. Abstracted through *Power Plant Engineering*, vol. 38, no. 9, September, 1934, p. 408, 1 fig., *d*)

Surface Condensers

THE author points out that in designs of condensers based on practical experience a certain empirical value for the rate of heat transmission K is taken. This value may be very much lower than experiments upon single tubes might lead the designer to expect. It is difficult to include the reasons for its small value in a worked out theoretical explanation, but it is known to vary according to a number of factors enumerated in the original article, among others, tube-plate arrangement. The application of any mathematical theory to a tube-plate layout is said to be impossible and thus each condenser designer has developed a different arrangement of the tubes.

Nor does the complication only end with the value to be adopted for the rate of heat transmission. The main business of a surface condenser is to remove heat from the steam. But for the best efficiency it should do so at constant temperature, i.e., the temperature of the condensate should be that of the steam at the turbine exhaust. This consideration has its effect upon the tube-plate arrangement, for especially in a large condenser there may exist between the turbine exhaust and the surface of the condensate a pronounced pressure drop. Since, in theory, the temperature of the condensate cannot exceed that corresponding to the pressure of the vapor immediately above it, the existence of a pressure drop results in an unnecessary loss of heat of the cooling water.

For these reasons certain features have been found advantageous by almost every maker. The tubes in the bank to which the steam first has access are openly pitched to encourage penetration; steam lanes devoid of tubes allow the steam to "blow" directly on the surface of the condensate, so that its temperature may be that corresponding to the vacuum, and a large proportion of the cooling surface is baffled from the rest to act as an air cooler. But when this sure ground has been left behind, each designer has his own views as to the best arrangement within the condenser shell. So complicated and interlinked, in fact, are the various factors influencing condenser design, that it is permissible to suggest that all modern designs are founded upon empiricism and upon experiments with actual plant in service rather than upon theories which accord closely with the results achieved.

Few matters in condenser design have given rise to more conflicting views than has the study of pressure drop. It is obvious enough that a drop of pressure must exist as between the turbine exhaust and the air suction in order to promote the flow of vapor through the condenser. But as between the entry to the condenser and the surface of the condensate there appears to exist a considerable difference of opinion, some claiming that between these points no drop in pressure need exist; others that there must be some drop, and others again that the condenser can be so designed as to give a negative pressure drop, i.e., a pressure rise. Sim, in his book, "Steam Condensing Plant," states that a pressure drop is necessary to initiate the steam velocity at entry to the condenser, and goes so far as to calculate its dimensions by equating the kinetic energy of the moving steam to pressure energy. But any such simple calculation is open to grave suspicion if only because the conditions within a condenser are so complicated. In any event, the energy represented by the velocity of the steam at entry to the condenser must be accounted for somewhere in the heat balance. As the steam passes over the tubes, part of it is condensed, so that, assuming other conditions unaltered, the volume of the remaining steam becomes less and less as the bottom of the condenser is approached. The areas of the passages through which it has to pass probably decrease at a proportionately much slower rate, so that it is to be expected that the velocity of the steam flow suffers a steady reduction between the top and bottom of the condenser. If Bernoulli's theorem is assumed to apply—and it is on this theorem that Sim appears to have founded his calculation—it would be natural under the circumstances to expect a recovery of pressure rather than a loss. Apart from any doubts there may be as to whether it is permissible to apply Bernoulli's theorem and as a result of the known difficulty of causing a gas to "compress itself" in this manner even in a well-designed diffuser pipe at anything but a very low efficiency, any pressure recovery will be at least partially balanced by the energy absorbed in forcing the steam through the tube banks. Under the circumstances, however, it seems unwise to state categorically that a negative pressure drop cannot exist as between the entry to the condenser and the surface of the condensate. There must, however, be a definite drop of pressure between the turbine exhaust and the air suction branch.

In this connection the English Electric Company, Ltd., of Rugby, has supplied some figures obtained from a medium-sized condenser some time ago. The tube-plate layout was similar to that described later in this article, but was not completely in accordance with the latest practise of the firm. A search tube was installed in the condenser steam space immediately below the tube nest and above the condensate. It was connected through a U-tube water gage with the top of the condenser. Readings obtained with this differential gage gave the positive pressure drops found in Table 1.

It is figures like these that make the existence of condensate

TABLE 1

Tube load, kw	Pressure drop, in. water	Temperature corresponding to mean vacuum at top of condenser, F	Temperature of condensate, F
No load	3.0	82.15	86
4000	7.3	90.3	86
6000	12.1	95.7	91.5
8000	13.9	97.7	96

temperatures in excess of those corresponding to the vacua at entry to the condenser seem too inexplicable. For the only way in which such temperatures can be accounted for in a manner which accords with theory is to assume a recovery of pressure in the condenser, such that the pressure at the bottom corresponds to the condensate temperature, while at the top it is lower by the amount necessary to give the steam its velocity. But the result of the test is to show that not only has no recovery of pressure taken place, but that there has been a definite drop, while the condensate temperature has been maintained at a high level. Nor will the supercooling phenomenon suggested by G. and J. Weir, Ltd., as an explanation meet the case under these circumstances.

The author considers the lack of uniformity in the flow of steam throughout the condenser and comes to the conclusion that the design of the tube-plate layout of the condenser is of very considerable importance. (Part of instalment 7 of a serial article, *The Engineer*, vol. 158, no. 4108, Oct. 5, 1934, pp. 326–327, illustrated, *t*)

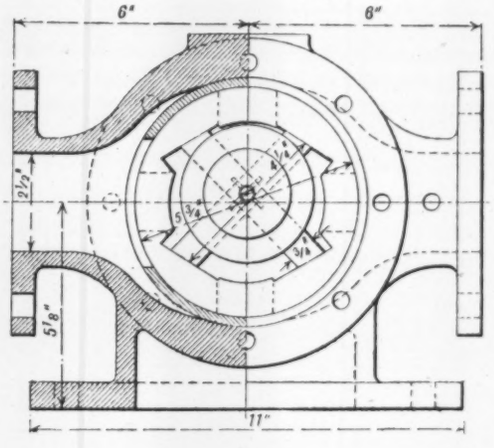
PUMPS

Rotary Pump

THIS rotary displacement pump is being manufactured by Plenty & Son, Ltd., of Newbury, England, and is intended primarily for the pumping of heavy oils and other viscous liquids. There are only four moving parts, namely, the driving shaft, a pair of blades or vanes, and an enveloping rotor, and these parts are quite substantial in dimensions. Thus, for instance, the blade of a $2^1/_2$-in. pump is $^3/_4$ in. thick (Fig. 7).

The casing is a simple casting with opposed inlet and outlet branches and a pair of end covers. In the covers there are bearings for the driving shaft which are eccentric to the bore of the casing. The latter has a hard cast-iron liner with ports to correspond to the branches and making a tight pressed fit. Within this there revolves the rotor, the cast-iron casting having four ports in its periphery and a bore with four flat inclined faces cut in it. These faces are very carefully machined so as to be parallel and equidistant. The driving shaft is supported in the eccentric bearings in the end covers, the outside one of which is a simple closed bearing, and the inside or driving end includes a stuffing box. Part of the shaft within the casing is pierced with two slots cut at right angles for the accommodation of the pumping vanes. It is also drilled to allow the oil being pumped to lubricate the bearings. The blades of brass take the form of an H and a hollow square, each measuring $4^1/_4$ by 5 in. by $^3/_4$ in. Their edges are beveled and they are made an exact fit between the flats and the rotor. The blades are beveled in opposite directions so that the pump can be driven either way and will not chatter through backlash.

The oil is sucked through the port in the rotor on the suction side by the increasing volume of the space bounded by the rotor, the shaft, and the blades as they rotate, and is expelled on the opposite side by the contraction of that space caused by the eccentricity of the shaft. During the revolution the slides must, of course, slide through the slots in the shaft and across the driving faces of the rotor, but as this movement is only to the extent of the eccentricity, no appreciable wear takes place, particularly because of excellent lubrication of the running parts and their generous proportions, Fig. 7. The rotating parts are in balance and it is stated that the tests carried out by the makers showed that it would pump oil having a specific gravity of 0.931 and a viscosity of 88 min 34 sec at 70 F at the rate of 2500 gal per hr against a pressure of 30 lb when running



ROTARY PUMP—VERTICAL SECTION

FIG. 7 PLENTY ROTARY DISPLACEMENT PUMP, VERTICAL SECTION

at 530 rpm. With Diesel fuel oil having a viscosity of 40 at 100 F, the delivery was 2650 gal per hr against 40 lb pressure when running at 530 rpm. (*The Engineer*, vol. 158, no. 4106, Sept. 21, 1934, p. 284, 3 figs., *d*)

Middle Level Pumping Station Equipment

THIS station is located at St. Germans, near King's Lynn, England.

A few of the somewhat unusual points in the pump design and manufacture may be of interest. When built up, the overall height of each pump is 23 ft 6 in. with a length over the shaft and outside bearings of 28 ft $3^1/_2$ in. To facilitate casting, machining, and transport, the volute of the pump was made in four sections, each comprising two parts jointed through the vertical center line, the largest being the part containing the smallest section of the volute, the cut water, and the discharge branch. The casting weights of this section were 11 tons 14 cwt, and were followed by the other volute sections in order of their development with weights of 5 tons 12 cwt, 9 tons, and 11 tons 13 cwt. The suction branches are in two parts, and the top half weighed 3 tons 5 cwt and the bottom half 4 tons 12 cwt. The impeller was cast in one piece and weighs 10 tons, and when keyed to its shaft this formed the heaviest lift, namely 14 tons. When keyed up, trued, and balanced, it was considered advisable to transport and erect this item in one unit, and the doors of the engine house were specially designed to admit it.

In the making of these pumps the foundry work followed the normal practise for heavy loam castings, and 1 per cent nickel was used in the mixture in order to insure soundness. Every casting came out sound, and matched, which, when it is realized that as much as 2 in. had to be allowed for cooling contraction on some of the sections, was no mean achievement. For machining the points of the volute section, a special milling and drilling machine was built with independent motor-driven

head. The boring of the built-up volute was done on a standard machine. A water-pressure test of 25 lb per sq in. was applied. The work of erecting the plant was in the early stages somewhat in the nature of field work, as the bottom halves of the pump with the discharge branch and valve, together with the suction branches and bell mouth, had to be incorporated. When the foundation work was placed in position and lined up, the pump parts were then built in as the mass concrete work proceeded, all of which made it a slow process, but, owing to the excellent facilities given by the engineer, this part of the work was successfully accomplished. So as to avoid distortion, dummy shafts were fitted, and the top half of the pump casings were then fixed in place. The final erection of the pump bearings and impeller and shaft, top of valves, etc., were left till the engine-house walls were finished and the crane was available. The satisfactory nature of the cooperation between engineer's staff on the concrete work and the contractors' was shown on starting up the plant, which operation went off without a single hitch, full load being put on within ten minutes of the first turn round.

A particular feature of the valve gear is a new automatic safety device, which has been provided to eliminate the possibility of accidentally switching on the motor while the handle for emergency manual operation is in engagement. This device takes the form of a housing surrounding the squared end of the operating shaft, and is closed by means of a hinged cover, in the hinge of which is incorporated a switch connected in series with the motor contactor gear. On opening the cover to engage the operating handle the contactor circuit is broken, and the motor cannot be started until the circuit is again completed by removing the handle and closing the cover completely.

The overall height of each of these valves is 24 ft $8^1/_4$ in., and the weight about 34 tons. A feature of the engine house is the convenience of control which has been assisted by such aids as marked tachometers, giving appropriate engine speeds for varying pumping heads, electrical heaters for cylinder jackets to facilitate starting, and the general heating of the engine houses by special stoves during the winter months. The controls are so interconnected that the three units can be run in a very simple manner from either engine house. (*The Engineer*, vol. 158, no. 4107, Sept. 28, 1934, pp. 303–307, 13 figs., *d*)

SPECIAL PROCESSES

Codeposition of Tungsten and Iron From Aqueous Solutions

THE paper does not present a description of a commercial process but shows that deposits of an alloy of tungsten and iron can be made. The deposits were analyzed and showed a variation of tungsten of from 55 to 68 per cent. The first deposits were bright and shiny, but later on were tinged blue or reddish bronze. A depleted bath gave again a bright and shiny deposit when used after a small amount of iron had been added and apparently it was the amount of iron that largely determines the appearance of the deposit. (M. Leslie Holt, paper before *The Electrochemical Society*, General Meeting, Sept. 27–29, 1934, abstracted from preprint 66-13, pp. 147–152, *d*)

STEAM ENGINEERING

Condition of Steam in the Cylinders of a Uniflow Steam Engine

WHILE the behavior of steam can be understood only when considered in connection with the variation of wall temperatures of an engine, this alone is not sufficient to determine precisely the processes occurring in the working cylinder. It becomes necessary to consider the actual state of the working steam as a means for comprehending the subject of variations in the state of the steam. This has been investigated by J. Ulsamer at the Thermodynamic Laboratory of the Technical High School in Munich. These tests were made on a uniflow cylinder without jacket or cover heating (bore, 350 mm; stroke, 600 mm; useful output, 100 hp). The pressures and temperatures could be measured. The tests were limited to the range of superheated steam but it is shown that this limitation was of less importance than one would be led to believe on the basis of hitherto existing views.

Fig. 8 is based on the average values derived from a considerable number of tests and shows the variation of temperature and pressure, the saturation temperatures, and the changes in the wall temperature. Two materially different processes in the cylinder must be differentiated. The first is the change of

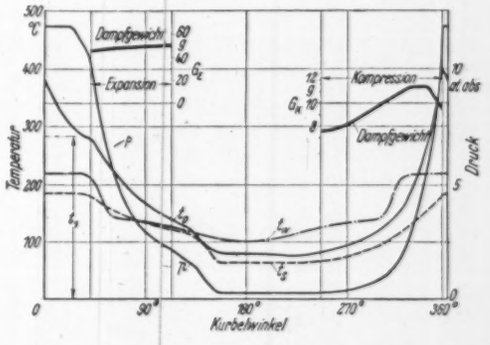


FIG. 8 VARIATION OF STEAM TEMPERATURE, PRESSURE, SATURATION TEMPERATURE, AND WALL TEMPERATURE WITHIN ONE CYCLE (1-to-1 load, 96 C superheat; *notation*, p, steam pressure in the cylinder in absolute atmospheres; t_D, temperature of steam, C; t_1, temperature of live steam ahead of the engine, C; t_s saturation temperature, C, corresponding to prevailing steam pressure; t_w, temperature of wall, C; *Dampfgewicht* = weight of steam; *Druck* = pressure; *Kurbelwinkel* = crank angle.)

state of the steam filling the cylinder chamber to within a close proximity of the walls. Here turbulence leads to approximately uniform temperature. The steam is superheated at all loads, even when the superheat of the steam supply is quite slight, while the cut-off, the expansion and compression, and with smaller loads also the exhaust periods are accompanied by superheat. At greater loads the steam during the exhaust approaches the state of saturation.

This change of state of the mass of steam takes place concurrently with a second process in the immediate proximity of the walls consisting of evaporation and condensation. The two phases, namely, superheated steam and liquid, coexist practically all the time.

The course of variations in the state of steam during the expansion and compression approaches more and more, with increasing superheat, to the adiabatic line, Fig. 9, this being clearly observable even at small superheats. The influence of the superheat of live steam on the state of the steam in the cylinder at the beginning of compression is slight. According to the load the amount of superheat varies from about 6 to about 20 C.

The weight of working steam may be computed for the expansion and compression (Fig. 8). The expansion, efflux of steam, and the first part of the compression are represented by the evaporation section, while the latter part of the compression and cut-off by the section corresponding to the condensation. During the compression particularly the weight of the

steam varies greatly, the walls being predominantly dry. Even though the condensation of the steam at the end of compression decreases the amount of steam in the cylinder, it is still considerably greater than that amount at the beginning of compression, on the basis of which the so-called "rest steam ratio" is computed. The ratio of the weight of steam at the beginning of cut-off to the weight of the live steam per cycle varies with the load, but is practically independent of the superheat of the live steam.

The course of condensation at the end of the compression is clearly a function of the superheat of the live steam, as this latter determines to a material extent the loci of the average

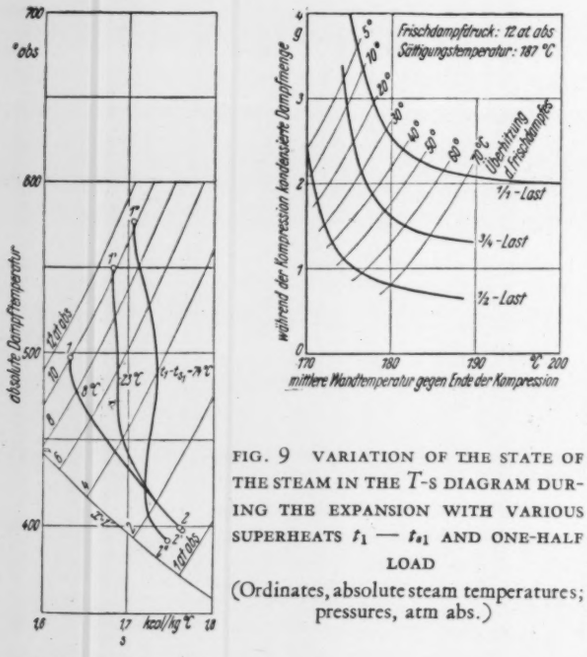


FIG. 9 VARIATION OF THE STATE OF THE STEAM IN THE T-s DIAGRAM DURING THE EXPANSION WITH VARIOUS SUPERHEATS $t_1 - t_{s1}$ AND ONE-HALF LOAD

(Ordinates, absolute steam temperatures; pressures, atm abs.)

FIG. 10 THE AMOUNT OF STEAM CONDENSED DURING THE COMPRESSION AS A FUNCTION OF THE AVERAGE WALL TEMPERATURES OF THE AREAS EFFECTIVE AT THE END OF THE COMPRESSION

(Abscissa, average wall temperatures at the end of the compression, C; ordinates, amounts of steam condensed during the compression. *Frischdampfdruck:* 12 *atm abs* = live-steam pressure, 12 atm abs; *Sattigungstemperatur:* 187°C = Saturation temperature, 187 C; *Last* = load; *Überhitzung d. Frischdampfes* = superheat of the live steam.)

temperatures of the boundary surfaces of the space in the cylinder in the proximity of the dead center, as a function of the saturation temperature corresponding to the pressure of the live steam (Fig. 10). Since the conditions of condensation, as long as the piston remains in the neighborhood of the inner dead center, do not change materially, the condensation during the cut-off is merely an extension of the condensation setting in at the end of the compression, and therefore varies approximately in the same way as the latter. Incidentally, this condensation determines the conditions prevailing on the surfaces inside of the cylinder and encountered by the live steam as it comes in.

Since at the beginning of cut-off the walls are partly covered by condensate the heat has to flow partly through dry sections of the walls and partly through layers of condensate. Because the coefficient of heat transfer at the dividing surface between steam and liquid is greater, the ratio of the areas covered by condensate to the dry areas determines the amount of heat transfer. In turn, because of this the condensation at the end of the compression determines the coefficient of heat transfer at the beginning of cut-off and this coefficient has a controlling influence on the heat exchange during the cut-off.

As the superheat increases the areas covered by condensate decrease. This produces a reduction in the coefficient of heat transfer opposed by the increase of the average temperature difference between steam and wall and increase in the heat content of the steam. The co-action of these two influences explains the remarkable behavior of the indicated efficiency. In the region of low superheats the decrease of the surfaces covered by the condensate exerts a predominant influence, and by reducing the heat transfer produces the comparatively great increase in indicated efficiency which has been observed. This is followed by a region where the two opposing influences come practically to a balance. In the region of the higher superheats the gain is fairly small because in that region the coefficient of heat transfer is also very small. The thermodynamic advantage of superheat lies in the influence on the temperature of the walls of the working volume of the cylinder, in so far as it affects the processes of condensation. The exceptionally fortunate distribution of temperatures along the walls of a uniflow-engine cylinder explains its success. (Dr. of Engrg. Julius Ulsamer in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 78, no. 25, June 23, 1934, pp. 779–780, 3 figs., *t*)

TEXTILE MACHINERY

High-Speed Pirn Winder

ACCORDING to the author there seems to be no logical reason why yarn should not be wound at the speed of a mile a minute, providing certain winding conditions are satisfied. The author is convinced that the commonly held notion that the material will not stand higher speeds is erroneous, and whatever troubles with high-speed winding occurred in the past were due to imperfections of mechanism. There has been, however, a great advance in engineering of winding machinery and with light-weight parts constructed with great accuracy and running in bearings scientifically designed for high-speed work under conditions of constant positive lubrication rotary speeds have been obtained which so greatly exceed those of former days as to be almost incomparable.

As a matter of fact a British concern has placed on the market a pirn winder operating at a spindle speed of 6500 rpm. Each spindle is a self-contained unit complete with its own traverse mechanism, clearer, tension device, hard-nose device, and broken-thread stop motion. The spindles are driven by friction, the drive being of entirely new design eliminating undesirable features which have hitherto been associated with this type of drive.

The main shaft of the machine, which runs lengthwise between the two rows of spindle boxes, is mounted in heavy double-row self-aligning ball bearings, fitted with Tecalemit pressure greasers. The driving frictions are made of a new material which is impervious to oil and water, is very hard, and has been specially selected for its durability. Each friction disk is securely bolted to a metal plate keyed on the shaft, so that it acquires maximum strength and accuracy of rotation. The edge of the friction disk drives a friction pulley mounted on the end of the pirn spindle which is the active agent for driving all the mechanism of each unit. The interior mechanism of each unit runs in its own oil bath, the oil being positively distributed through a chain conveyer which rotates with the spindle. (*Silk Journal and Rayon World*, vol. 11, no. 121, June 20, 1934, pp. 32–33, 4 figs., *d*)

A.S.M.E. Boiler Code

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of this Committee in Cases Nos. 746, 781 (reopened), 783, 784, 785, 786, and 787, as formulated at the meeting of September 14, 1934. They have been approved by the Council. In accordance with established practise, names of inquirers have been omitted.

CASE No. 746

(Annulled)

CASE No. 781 (Reopened)

(*Interpretation of Par. U-36*)

Inquiry: In the application of the fifth section of Par. U-36 of the Code, should the required thickness of the head as determined by the head formula be used in determining the amount of reinforcement required, or should the required thickness of a shell as determined by Par. U-20 be used in fixing the amount of head reinforcement required?

Reply: It is the opinion of the Committee that the thickness to be used in applying the requirements of the fifth section of Par. U-36 shall be that of the shell when computed in accordance with the requirements of Par. U-20, using $E = 0.90$.

CASE No. 783

(Annulled)

CASE No. 784

(*Interpretation of Par. U-72*)

Inquiry: May the excess thickness of the flange of a head be removed from the outside of the flange instead of from the inside as required by Fig. U-17 under the provisions of Par. U-72?

Reply: It is the opinion of the Committee that the removal of the excess thickness of plate from the outside instead of from the inside of the flange or the head as shown in Fig. U-17, will meet the intent of the requirements of Par. U-72.

CASE No. 785

(*Interpretation of Pars. U-120 to U-138*)

Inquiry: May the recently promulgated Rules for Vessels Subjected to External Pressure be used to determine the wall thicknesses of tubes subjected to collapsing pressure and used in unfired pressure vessels, when such tubes are rolled into tube sheets and not otherwise supported?

Reply: It is the opinion of the Committee that the Rules for Vessels Subjected to External Pressure may not be applied to the determination of tube wall thicknesses. It is pointed out that these rules are limited in their application to the three general types of vessels shown in Fig. U-19.

CASE No. 786

(In the hands of the Committee)

CASE No. 787

(In the hands of the Committee)

Errata

ATTENTION is called to three typographical errors appearing in the recently issued addenda to the A.S.M.E. Power Boiler Code as follows: Page 126, "Par. P-195 Revised" should read "Par. P-9 Continued;" page 132, Par. P-268*b*, "Delete the third section" should read "Delete the second section;" page 135, at the end of the first paragraph the words "fourth section" should read "fifth section."

Design of Bolted Flanged Connections

(*Continued from page 738*)

of no taper in the hub, computing h, and then using the average values of B and g that result from this value of h in the formulas for the stress.

Furthermore, it makes no difference whether this value of h brings the effective hub length to a termination in the flange hub, in the butt weld, or in the shell. The designer is justified in making this assumption of a value for h, since increasing the length of the hub beyond this amount adds practically nothing to the strength of the design.

In the design of loose flanges the designer is free to use either plain rings or hubbed flanges of any hub height. He, however, should study the effect of hubs on flanges to realize the economy of the hubbed flange over the plain ring for any given set of conditions. He is also free to use any hub height he desires, but he should study Fig. UA-3 or Fig. 10 to get a clear picture of the stress-reducing value of hub height. Increasing the thickness of the hub increases the strength of the design faster than increasing the height. The hub thickness should therefore be the largest permitted by the bolting and there should be a fillet at the junction between the back of the flange and the hub, even more generous than that required by the rules. The first step, therefore, in the design of the hub of a loose flange is to establish the outside diameter of the hub. Then the designer arbitrarily selects a value for h.

Having tentatively determined the hub proportions for either the integral or loose type of flange, the stresses are computed from the formulas using the value of t previously selected. If either one of these stresses is too high, a larger value of g or h should be tried (in the case of loose flanges) until a satisfactory stress condition is obtained. In all cases the stress can be lowered also by increasing the thickness of the hub or that of the ring. If it is impossible to obtain reasonable stresses by varying the hub dimensions, it will be necessary to increase the ring thickness t. On the other hand, if the computed stresses are low it will be desirable to decrease t.

Such a set of rules as the ones under discussion cannot be perfect at the first writing. It is hoped by the authors that every designer will keep a record of all joints designed, with particular reference to contact-pressure ratio used in conjunction with the schedule of working stresses set up in the codes so that a body of data can be collected on this subject. Designers should remember that modifications and improvements cannot be made if they do not report their experience.

Early U. S. Steam Tables

(*Continued from page 717*)

as well as a most convenient pressure-entropy table. A table of thermal properties of water was added in which the density of water was taken apparently from the values derived or suggested in the Marks and Davis tables. The specific heat was probably computed by his indirect determination of the heat content of the liquid. He used 777.64 ft-lb as the mechanical equivalent of heat and the mean Btu of Marks and Davis was the heat unit used.

In 1921 the pressures and superheat of 1890 were greatly exceeded and although the improved steam tables gave more consistent results for the earlier steam conditions, when the tables were used for prevalent pressures and superheats the values of properties for the same points on various American and foreign tables were so different that engineers desired the same thing as that expressed by Thurston in 1890 when he said: "It would be a great boon to the engineer to secure such a comparison of authorities, so-called, as would determine definitely the extent, reason, and effect of such discrepancies and the relative accuracy and value of the several tables for his purposes."

There were two men in the United States who had the vision to make this wish of Thurston a reality for American engineers. I refer to Mr. Geo. A. Orrok and President Harvey N. Davis, who called a meeting of fourteen men interested in the use of steam tables at Harvard University on June 23, 1921, for the purpose of outlining a plan for American investigations of the properties of steam and water and a method of financing them.

In the discussions of this group the necessity of extensive investigations of the properties of steam to higher limits than those previously used was emphasized regardless of the effect on any formulation current at that time.

The work in the United States at three centers of research resulting from this meeting and the international steam tables conferences to correlate this work with that at other centers for the purpose of producing an international steam table or different tables within certain ranges of tolerance is familiar to all of you, but I wish at this time to pay my tribute to the men who initiated and organized the support of the work in the United States for further determinations of the properties of steam.

Control of Distribution

(*Continued from page 722*)

In this paper we have approached the problem of distribution from the point of view of standards which appear to be just as essential in the control of problems of distribution as they are in connection with manufacturing problems. Since frequently in problems of distribution it is not possible to measure all the detailed elements, each of which may be important in making up the quality of a market or the quality of the distribution system, it is necessary to use statistical data which reflect the quality element directly. Such data are not measurable quantities since they represent merely counted items of the same kind. It has been pointed out that the analysis of these attribute counts differ from the analysis of variables which are commonly considered in studies of statistical method.

In particular, the importance of the two elements of standards and data type in the field of distribution has been illustrated by a problem of newspaper circulation and a problem of market analysis. It has been shown that it is possible in the case of newspaper or magazine circulation to set up standards in relation to which it is possible to judge the significance of the actual data as collected.

In the case of the problem in market analysis it has been shown that the powerful tool of cross-classification needs further analysis in order to decide whether the different standards apparently set up in the cross-classification table are real or are possibly the results of the particular sample which has been gathered in the investigation.

Because of the limitations of time the problems of sampling, the questions of setting up proper standards in connection with other groups of distribution problems, and more important still the question of the use of standards in relation to the observed facts and their interpretation in connection with the profit-and-loss statement of the business have had to be omitted. Treatment of these may be found elsewhere.

The Technique of Marketing Research

(*Continued from page 724*)

and fineness of the grind, (4) the temperature at which the brewing is conducted and the promptness with which the finished brew is served, and (5) the type and cleanliness of the vessel used for brewing.

It is well enough to pursue an investigation of this sort on one's own ideas and opinions but we have been often surprised to learn what the ultimate consumer, in this case the housewife, considers important. In the last analysis she is the one who buys these devices, does the brewing, and must be satisfied. By a preliminary survey of her attitude and desires we had not only indisputable information as to what she considers important when purchasing a coffee pot and when making coffee, but, furthermore, we had information on the relative importance which she attaches to the various attributes of a coffee pot. For example, we found that she wants good coffee without too much trouble; she wants it quickly and with a minimum chance of failure. She would like to have efficient extraction if that can be done without lending a bitter taste to the coffee. She wants a burn-proof handle, a pot that is durable, one that is easy to clean.

I shall not go into the details of this investigation, but I want to point out that in this type of study we first accumulate the necessary background information and then consult a sufficient number of consumers to obtain a reliable picture of what is expected of the product under consideration. We then purchase samples of all these products, proceeding to the laboratory where all samples are impartially subjected to the most severe tests we can conceive of.

During this procedure we gradually evolve the criteria of quality for an ideal product of its type and every unit is rated on each criterion. When this has been done intelligently, there is little doubt as to which product at its regular price represents the best value for a consumer. In studies of this character it is necessary to give careful attention to the matters of price, dealer reaction, and design as the article must be salable as well as efficient.

It is astonishing to discover how few manufacturers have apparently designed their products from the standpoint of the ultimate purchaser. Articles made by some of the largest and best known firms have been found to be poor value when compared with like products on the market at the same or a lower price. Had these companies made a study of the type to which I have referred this would certainly have dictated either a modification in design or a discontinuance of the article.

Thousands make hundreds by selling what people should have, while hundreds make millions by selling what people want.

Correspondence

Logarithmic or Parabolic?

TO THE EDITOR:

In December, 1924, the *Journal of the Franklin Institute* published one of my papers entitled, "A New Theory of Fluid Flow" (abstracted in MECHANICAL ENGINEERING[1]). This paper showed by experimental data from various reliable sources (A.S.C.E., Roy. Soc. London, and others) that the velocity distribution for steady flow in long, straight pipes of circular cross-section is logarithmic, regardless of whether the rate of flow is above or below the critical value.

There was considerable comment on this paper, some unfavorable and much favorable. The most interesting thing however is that in no case was any critic able to produce data for a velocity-distribution curve, the points of which could be better fitted by a parabola than by a logarithmic curve. The differences between the two curves become progressively less at lower and lower rates of flow, but the logarithmic velocity distribution is nevertheless vital to the remainder of the theory developed.

More recently I have been able to develop this fluid-flow theory to the point where it explains very simply many hitherto unexplained flow phenomena—including the characteristic change from streamline to turbulent at the critical flow rate. I am hesitant about making this rather radical claim publicly, and would first like to ask your readers (by publishing this letter) whether any of them know of data, the accuracy of which is reasonably established, which can be better fitted by a parabola than by a logarithmic curve.

The inability of the critics of the logarithmic-velocity-distribution theory to produce experimental data showing parabolic-velocity distribution is beginning to convince me that such data not only do not exist but that parabolic-velocity distribution probably cannot be obtained in any carefully conducted test, regardless of the nature of the fluid or its rate of flow.

ANTHONY BRUCE COX.[2]

Pittsburgh, Pa.

Towl on Pipe-Line Flow

TO THE EDITOR:

The first supply, 500 copies, of my book on *f*, the pipe-line flow factor,[3] has been distributed, without cost, to engineers, scientists, and educational institutions.

I have had an additional supply of Part I delivered to this office. A copy will be sent to any one whose application is accompanied by a check for $2.50 made to the order of Cornell University and *sent to me at this office*.[4] The entire proceeds of such sale will be used toward defraying the cost of apparatus required for making tests at Cornell University to establish the relation between water and other liquids and air and other gaseous fluids when flowing through pipes under turbulent-flow conditions.

FORREST M. TOWL.

New York, N. Y.

[1] MECHANICAL ENGINEERING, vol. 47, no. 3, March, 1925, pp. 205–206.
[2] Mem. A.S.M.E.
[3] Announced in MECHANICAL ENGINEERING, October, 1934, p. 634.
[4] Room 2611, 26 Broadway.

Books Received in the Library

A.T.M., Archiv für Technisches Messen. Nos. 31–38, January, 1934–August, 1934. R. Oldenbourg, Munich and Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 1.50 rm. each. The Archiv für technisches Messen is an application of the loose-leaf method to encyclopedia production. The text consists of brief articles upon measuring instruments and methods for all industrial and scientific purposes, together with summaries of accepted practise and reports upon research work, new instruments, etc. Each topic is handled by a specialist, and other papers are classified for convenient filing. The present numbers cover a wide variety of hydraulic, acoustical, chemical, and electrical measurements. No. 36 contains an index to the first thirty-six issues.

DIE ABFLUSSERSCHEINUNGEN UND DRUCKVERHÄLTNISSE AN KLAPPENWEHREN, Untersuchungen aus dem Flussbaulaboratorium der Technischen Hochschule Karlsruhe. By H. Schwarzmann. R. Oldenbourg, Munich and Berlin, 1934. Paper, 8 × 11 in., 41 pp., illus., diagrams, charts, tables, 3.80 rm. This work records the results of extensive experiments with a model, which give a clear picture of pressure conditions in shutter weirs. Upon the basis of these experiments, the flow over weirs was investigated generally and the factors that determine its amount established.

CODES, CARTELS, NATIONAL PLANNING, the Road to Economic Stability. By B. Burn in collaboration with S. Flink. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 413 pp., diagrams, tables, $4. The author of this study has had long experience in the management of cartels and trade associations in Germany. In the light of this practical knowledge, he here discusses the influence of our present codes upon economic stability, the possible ways in which cut-throat competition and over-expansion can be checked, the organization of American business for self-administration, and the compatibility of national planning with American institutions.

DAVISON'S TEXTILE BLUE BOOK. Handy edition, sixty-ninth year, July, 1934–July, 1935. Davison Publishing Co., New York. Leather, 5 × 8 in., 1282 pp., maps, $5. This well-known work is now available for the sixty-ninth year, July, 1934, to July, 1935. As in previous issues, it forms a complete directory of the American textile industry, with the essential information about the capital, officers, equipment, and products of each mill, dye-house, etc. State maps show the location of manufactories. The material is conveniently arranged and fully indexed.

ELECTRON TUBES IN INDUSTRY. By K. Henney. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 490 pp., illus., diagrams, charts, tables, $5. The purposes of this book are to describe in one place sufficient industrial applications of thermionic and light-sensitive electron tubes, to explain the fundamental principles involved, and to describe rather fully the newer tubes which are not generally known. The work is a useful survey of a new field, which will obviate the necessity of consulting much scattered periodical material, and call attention to many industrial applications.

ENGINEERING RADIOGRAPHY. By V. E. Pullin. G. Bell & Sons, Ltd., London, 1934. Cloth, 8 × 11 in., 136 pp., illus., diagrams, charts, tables, 45s. This work is intended to be a practical guide to the radiologist in interpreting radiographs of forgings, castings, and other engineering structures. A comprehensive collection of radiographs is presented, showing all the chief and most common flaws in castings, accompanied by photographs of sections of the castings which show the actual conditions. The causes of the flaws are explained in terms of common engineering experience. The author, who is Director of Radiological Research at Woolwich, has produced a manual which will be of value to all interested in the examination of materials by means of X-rays and radium.

METALLOGRAPHIE DES ALUMINIUMS UND SEINER LEGIERUNGEN. By V. Fuss. J. Springer, Berlin, 1934. Cloth, 6 × 10 in., 219 pp., illus., diagrams, charts, tables, 22.50 rm. The purpose of this work is to review the existing literature on the metallography of aluminum and its alloys in a form adapted to the needs of mechanical engineers and works managers. The metallography of the industrial binary and ternary alloys is discussed, and there are chapters on heat treatment and crystallization. Numerous photomicrographs and phase diagrams are given and there is a bibliography.

SCHWEIZ. VERBAND FÜR DIE MATERIALPRÜFUNGEN DER TECHNIK. (Association Suisse pour l'Essai des Materiaux.) Diskussionsbericht No. 28, Bericht No. 71 der Eidg. Materialprüfungsanstalt. Mikroskopische Untersuchung mattierter Kunstseide, by R. Lassé. Zürich, November, 1933. Paper, 9 × 12 in., 18 pp., illus., tables. Reports an extensive investigation of methods for giving a matt finish to rayon.

TECHNIQUE OF MODERN WELDING. By Prof. P. Bardtke; translated from the Second German edition by H. Kenney. Blackie & Son, Ltd., London and Glasgow, 1933. Cloth, 6 × 9 in., 299 pp., illus., diagrams, charts, tables, 15s. This work aims to fill a double purpose by giving a survey of welding technique which will be of use to engineers and also providing a manual for the training of welders. Part one discusses welding processes, part two the applications of welding and the testing of welds, and part three gas cutting. The author is director of the welding-repair shop and welding-research department of the German State Railways. The translation is based on the second German edition, with revisions and amplifications by the author.

TEXT-BOOK ON HYDRAULICS. By G. E. Russell. Fourth edition. Henry Holt & Co., New York, 1934. Cloth, 6 × 9 in., 447 pp., illus., diagrams, charts, tables, $3.90. A clear, logical presentation of the fundamental principles of hydraulics, intended for students and as a reference book for engineers. The results of recent research work are included, and references to sources are given. This edition has four new chapters on hydraulic turbines and pumps and an appendix giving a general treatment of fluid flow in pipes, covering the problems presented by other fluids than water.

WATER-POWER ENGINEERING. By H. K. Barrows. Second edition. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 762 pp., illus., diagrams, charts, tables, $6. The principles and practise that underlie the design of hydroelectric plants are described in a comprehensive way in this textbook, which is based on the course in the subject given at the Massachusetts Institute of Technology. Useful information upon modern stations and their equipment is included and many practical data are given. The new edition has been carefully revised to bring it up to date; this is especially true of the section on the cost and value of water power, which has been largely rewritten.

WORLD POWER CONFERENCE, SECTIONAL MEETING, SCANDINAVIA, TRANSACTIONS 1933, 7 Vols. Svenska Nationalkommitten för Världskraftkonferenser, Stockholm, 1934. (American Committee, World Power Conference, 1419–21 Chrysler Building, New York.) Cloth, 6 × 10 in., illus., diagrams, charts, tables, 7 vols., 175 Swedish Kroner. These seven volumes contain a full report of the papers and discussions before the technical sessions of the Conference, of its organization, personnel, official and social functions, etc. The theme of the Conference was the energy problems of large-scale industry. One hundred and seventy-four reports were presented and these, with the ensuing discussions, appear in these volumes. The individual volumes are: 1, General matters, general summaries of all reports, and the index to the transactions; 2, Electrical energy; 3, Gas, and solid and liquid fuels; 4, Power and heat combinations, and steam-heat consuming industries; 5, Iron and steel industry, electrical heating, and the transmission and adaptation of motive power for industrial machinery; 6, Railways, and urban and suburban traffic; 7, Marine transport. The set affords a valuable review of current practise and thought upon the energy problem.

Individual volumes or complete sets can be purchased from the American Committee, World Power Conference, 405 Lexington Ave., New York.

Vol. 1, 763 pp., $14; vol. 2, 702 pp., $14; vol. 3, 336 pp., $7.25; vol. 4, 615 pp., $12.75; vol. 5, 692 pp., $14; vol. 6, 781 pp., $16; vol. 7, 294 pp., $5.50. These prices are approximate and vary according to exchanges.

WHAT'S GOING ON

Actions of the A.S.M.E. Executive Committee

AT its meeting on October 24, the Executive Committee of The American Society of MECHANICAL ENGINEERS took the following actions of general interest.

CALVIN W. RICE

A committee was appointed consisting of Dexter S. Kimball, chairman, David S. Jacobus, and Alex Dow to prepare resolutions on Calvin W. Rice for presentation at the business meeting, December 3. Dr. Harvey N. Davis was appointed chairman of a committee to consider suggestions on memorials to Dr. Rice. It was reported that Dr. John H. Finley, editor of the *New York Times*, would deliver an address at 4:30 p.m., December 5, on Dr. Rice's contributions to international friendliness.

A committee, consisting of Past-Presidents W. F. Durand, chairman, W. L. Abbott, C. N. Lauer, A. A. Potter, and President Doty, was named to consider the appointment of a secretary and report at the Council meeting in December. The executive secretary was authorized to carry out the duties of secretary until the new appointment is made.

ENGINEERING INDEX

An agreement was reported covering terms of the lease of the Engineering Index to the new corporation, Engineering Index, Inc., that has taken over this service. Announcement of the change will be found in MECHANICAL ENGINEERING, September, 1934, page 573.

SURVEY OF PROFESSION

It was reported that under the leadership of the Engineering and Allied Technical Professions Committee of the American Engineering Council, in cooperation with the Bureau of Labor Statistics of the Department of Labor, a survey of the engineering profession is to be undertaken to bring out the present and recent conditions of employment of engineers, duties, salaries, and educational background.

MEMBERSHIP STATUS

Upon recommendation of the Board of Review it was voted that a member who chooses to pay at a future date all dues arrears canceled when loss of seniority was approved can by such payment regain his original date of election with full seniority privileges.

Deep appreciation was expressed of the service of the Board of Review, and it was voted to continue the Board for the remainder of the calendar year.

ANNUAL REPORT APPROVED

The Annual Report of the Council (published as section 2 of the November Transactions) was approved.

WASHINGTON EMPLOYMENT SERVICE

Upon recommendation of the Capital-Goods Industries Committee, the American Engineering Council was requested to make a study of the service necessary for continuous contact between the agencies of the Federal Government which are employing engineers and the Engineering Societies Employment Service. This study was made and presented to representatives of the four Founder Societies which agreed upon the wisdom of a Washington office. Upon recommendation of the Capital-Goods Industries Committee and with the approval of the Finance Committee and the Executive Committee of the Council, it was voted to authorize the expenditure of $1000, part of the cost of maintaining a Washington employment agency which will serve as a contact between the Engineering Societies Employment Service and the Federal Government bureaus in Washington, with the following stipulations: (1) That the other three Founder Societies join this undertaking; (2) that the appropriation shall be an emergency one for one year only; and (3) that the continuance of this emergency appropriation shall be based on a complete report made to the Council during May or June of 1935.

APPOINTMENTS

It was voted to continue the present representation of the Society on the American Engineering Council. These are Paul Doty, L. P. Alford, Ralph E. Flanders, D. Robert Yarnall, and A. A. Potter.

W. L. Batt was reappointed as one of the three A.S.M.E. representatives on the Board of the United Engineering Trustees, Inc.

Personnel of Power Test Code Committee No. 21 on Dust Separating Apparatus was approved as follows:

Edward L. Anderson	Melvin D. Engle
James W. Armour	H. F. Hagen
Alex D. Bailey	P. H. Hardie
Hudson H. Bubar	Carl W. Hedberg
Huber O. Croft	James H. Leech
J. M. DallaValle	H. E. Macomber
Philip Drinker	Benjamin F. Tillson

James C. Hobbs, Edward H. Barry, and F. M. Gibson were appointed on the Joint Committee on the Study of Coal, announced in MECHANICAL ENGINEERING for August, page 510.

The following Honorary Chairmen of A.S.M.E. Section Branches were appointed: F. O. Ellenwood, Cornell University; W. E. Reuling, Michigan State College; F. S. Griffin, University of Akron; R. M. Barnes, State University of Iowa; John A. King, University of Kansas; I. H. Prageman, University of Maine; and E. L. Sussdorff, University of Vermont.

LETTER TO PRESIDENT ROOSEVELT

A letter to the President of the United States asking consideration for the greater use of civilian engineers in public works was approved. The letter follows:

HIS EXCELLENCY
THE PRESIDENT OF THE UNITED STATES
SIR:

The opportunity to present to you the following through Messrs. Philip Hiss and Stephen Voorhees, is appreciated by the undersigned officers of national organizations of professional engineers whose interests are incident to construction:

The engineering profession has been seriously affected by acts of the Government to which we would call your attention:

Administrative officers of the Federal Government (1) have exhibited it to be their policy to remove public work from engineers normally so engaged, causing this work to be brought into Federal Departments or Bureaus, and (2) have questioned the established methods of paying for engineering services on a percentage fee basis.

While recognizing that it has always been appropriate for the Federal Government to provide technical supervision over construction projects in which the Government is inherently a part at interest, we wish to protest against the newly developed policy of expanding Federal Bureaus into the design, consultation, and supervisory functions incident to construction. The Government is thus depriving engineers in private practise of one of the few sources of income at present remaining in sight.

The Federal Government is participating with other political divisions and subdivisions in public works, the design and supervision of which is normally performed by engineers in private practise as for a client on a fee basis. The removal of the fee system or the decrease of the established fee rates as sponsored by Federal authorities deprives engineers of a normal source of income. Design is always a proportionate part of the cost of a structure and fair and just percentage fees have long been established. It appears that the services involved are not understood by the administrative officers who seek to change these fees.

It is requested that the President provide the opportunity for a clear understanding of this situation by the appointment of a representative committee of engineers, which committee should submit to the President a fair basis for the engagement where practicable on Government work of private engineers and their organizations.

GEORGE T. SEABURY, *Secretary*,
American Society of Civil Engineers
C. E. DAVIES, *Executive Secretary*,
The American Society of Mechanical Engineers
A. V. HUTCHINSON, *Secretary*,
American Society of Heating and Ventilating Engineers
FREDERICK M. FEIKER, *Executive Secretary*,
American Engineering Council

R. F. C. Loans

AT THE request of Jesse H. Jones, Chairman, Reconstruction Finance Corporation, the following letter, explaining the Corporation's authority and policy with respect to direct loans to industry, is published:

Industrial concerns, eligible to borrow funds from the Reconstruction Finance Corporation for the purpose of maintaining and increasing employment, have not yet taken full advantage of the assistance which the Corporation is prepared to extend.

Congress provided that such loans might be made to industrial and commercial businesses subject to the following requirements:

(1) That the business must have been established prior to January 1, 1934.
(2) That such loans be adequately secured.
(3) That maturity of loan must not exceed five years.
(4) That borrower must be solvent at the time of disbursement of the loan.
(5) That credit at prevailing bank rates for loans of the character applied for not be available at banks.
(6) That reasonable assurance of increased or continued employment of labor be given.
(7) That the aggregate of such loans to any one borrower made directly or indirectly shall not exceed $500,000.
(8) That such other provisions as the Reconstruction Finance Corporation may impose be complied with.

The Directors of the Reconstruction Finance Corporation feel that these loans should be made in such a way that the available funds can be utilized as fully as possible for the advance of permanent business recovery. This objective can be accomplished best if the moneys loaned by the Corporation are used principally to supply funds for the payment of labor and the purchase of materials incident to the normal operation of the business, rather than for the payment of existing indebtedness, though in exceptional cases a small part of the loan may be used for payment of existing debts or for the financing of construction, improvements and/or repairs that do not materially increase capacity. When a loan is to be used primarily for labor and materials, a small portion of the loan may be applied to these latter purposes when necessary to assure ordinary and efficient operation.

The Corporation will make loans in cooperation with banks, or by the purchase of participations in loans made by banks. In cases of national banks, only the bank's participation in such loans, rather than the full amount of the loan, must be within the legal limit which may be loaned to any one customer, and accordingly this plan will allow substantially greater credit to be extended through such channels to borrowers who are already borrowing up to their legal limit.

The depression years have left many enterprises in very much involved and weakened positions, but our experience has led us to believe that where present creditors are willing to cooperate by a proper adjustment of existing debt structure, many such enterprises may be safely supplied with additional funds that will enable continuing operations on a sound basis.

Accordingly, we suggest to industrial concerns, to which credit at prevailing bank rates for loans of such character is not available but which can offer adequate security (even though such security may be frozen and therefore not generally acceptable to banks) and which can profitably use additional funds for labor and materials, that they communicate with the local loan agency of this Corporation serving the territory in which such concerns are located.

John Fritz Medal Awarded to Sprague

TO FRANK JULIAN SPRAGUE, for "distinguished service as inventor and engineer through the application and control of electric power in transportation systems," the John Fritz gold medal for 1935 was awarded unanimously by the John Fritz Medal Board of Award at its annual meeting, October 19, 1934. The presentation was to have been made with suitable ceremony at one of the sessions of the Winter Convention of the American Institute of Electric Engineers late next January. Unfortunately, Dr. Sprague's death occurred early in the morning of October 25, only a few days after the notification was sent to him that the medal had been awarded.

This is the thirty-first award of the highest distinction bestowed by the national societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers of the United States, for "notable scientific or industrial achievement." Among the recipients have been Lord Kelvin, Thomas A. Edison, Guglielmo Marconi, Elihu Thomson, John R. Freeman, John E. Stevens, Elmer A. Sperry, Daniel C. Jackling, Michael I. Pupin, J. J. Carty, J. Waldo Smith, to mention a few at random. The Board of Award is composed of 16 past-presidents of the societies named.

Dr. Sprague was a past-president of the American Institute of Electrical Engineers, and a member of numerous other engineering and scientific societies in America and Great Britain. He had also previously received the Franklin Medal and the Elliott Cresson Medal of The Franklin Institute, medals at the Philadelphia Electrical Exposition, the Paris Exposition of 1889, and the Louisiana Purchase Exposition.

Sprague was graduated from the U. S. Naval Academy in 1878. In later years he received honorary degrees from three institutions of higher learning, Doctor of Laws, University of Pennsylvania; Doctor of Engineering, Stevens Institute of Technology; Doctor of Science, Columbia University

Sprague resigned from the Navy in 1884 to join Edison in developing electric lighting systems. Later he became interested in the application of electricity to elevators in buildings, to street railways, and to electrification of steam railroads, in several countries. Among his inventions are many relating to electric motors, multiple-unit systems of train control and operation, electric street railways, and high-speed elevators.

He was a member of an electrical commission in charge of electrification of the New York Central Railroad, New York City, and co-inventor of the protected third rail. He was chairman of committees on electricity and ship construction of the U. S. Naval Consulting Board during the World War. He was an advocate of direct-current railway operation.

Ambrose Swasey Honored

THE twentieth anniversary of the Engineering Foundation was celebrated with a dinner at the Union League Club, New York City, on October 18. The guest of honor was the founder, Ambrose Swasey, of Cleveland, past-president and honorary member, A.S.M.E., who will be eighty-eight years old on December 19.

Dr. Swasey was presented with a memorial volume containing an address of felicitation and bearing the signatures of the seventy engineers and scientists who united to acclaim him as the one whose foresight and generosity brought about in 1914 the establishment of the Foundation as a unique and beneficent institution. The address declared that, although the contributions of the Foundation have been great, they mark but the beginning of far greater service in the future.

"In the twenty years since you made your first gift," the address continued, "there has been a steady growth in appreciation of your great conception of an institution through which the cooperative activities of engineers, scientists, and industrialists could contribute by research, and in other ways, to the advancement of the profession of engineering and the good of mankind."

Replying to the presentation remarks of Harry P. Charlesworth, chairman of the Foundation, who acted as toastmaster, Dr. Swasey said that the friendship of the men who were gathered about him was worth more than all that he had ever contributed to the Foundation. The extent of his contributions, he added, was small when compared with the achievement of those who have directed the work of the Foundation during the past fifth of a century. Dr. Swasey added that in establishing the Foundation he had simply erected a stage for the future. He foresaw that during the next century the destinies of the Foundation would be guided by a succession of high-minded men responsive to the duty and opportunity of carrying out the Foundation's mission as an instrument of the engineering profession for the good of mankind.

The address to Dr. Swasey was signed by the officers of the American Society of Civil Engineers, The American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Electrical Engineers and of kindred technical societies and associations of scientists, together with present and former members of the United Engineering Trustees and the Engineering Foundation and other friends.

Speakers at the dinner and their topics were Dr. Frank B. Jewett, former vice-chairman of the Foundation, "A Unique Foundation;" and Dr. Karl T. Compton, president, Massachusetts Institute of Technology, "Its Future Opportunities." An address, "Appreciation by the Societies," by Harold V. Coes, president of the United Engineering Trustees, Inc., was read in Mr. Coes' absence by George L. Knight, vice-president of the Trustees. Messages were read from Gano Dunn, first chairman, and Prof. Michael I. Pupin, second chairman, of the Foundation.

Discussing the opportunities of the Foundation, President Compton pointed out three important lines of development. The first is the developing of research men, and, incidentally, research fields; second, the fostering of new projects; and, third, encouragement of projects of a cooperative type.

"Science," President Compton said, "is becoming more complex; engineering is becoming more complicated; consequently it is becoming more and more necessary, in carrying out things of major importance, to enlist the cooperation of qualified groups.

"The greatest opportunity of all for a foundation is to supply the vision and the organization which are necessary to set up these cooperating groups and start them in action. With these three functions, and certain other functions that I have not mentioned, there is no doubt but what there is a temendous opportunity for service ahead of the Engineering Foundation."

President Compton cited the work of the Engineering Societies in establishing the Engineers' Council for Professional Development, and in attacking cooperatively the problem of earths and foundations, particularly foundations on difficult types of soil, as examples of effective effort in aiding projects to get under way.

He outlined "the tremendous record," made by foundations, quoting Dr. Frederick P. Keppel, president of the Carnegie Corporation, as stating that there are about 129 foundations with aggregate funds of about $800,000,000, and that seven of these foundations have already disbursed in excess of $280,000,000. President Compton felt that "these great altruistic foundations are characteristically American products." He thought that the standard routine jobs which are necessary for carrying in fields of education and public health, scientific work, etc., are definitely government jobs, because they are for the people.

However there are certain other fields of the pioneering, development type, which have to be done, and which must be done, by the government if not otherwise, but which have been done in very large part up to the present as a result of benefactions from individuals, and, largely, through these foundations.

"Dr. Swasey, I think, is one of the men who like to have this kind of fun, and as long as there are enough men like him who desire to have this kind of useful fun, then I think we shall be able to continue the development of these important aspects of public welfare in the ways in which they have been developed in the past."

The Engineering Foundation, Dr. Jewett said, is unique in its character, in the character of its governing board, in the character of the man who gave it being, and in the engineering field.

"This is a great Foundation," he said, "not in the sense of many foundations if you measure them by the money at their disposal to spend, but great in the opportunity which it gives all engineers in this and in following generations to exercise a power for doing something either for the profession or, as the charter says, for the good of mankind.

"It is a democracy among foundations. The charter gives enormous latitude of operation with changing conditions as time goes on. The board is not self-perpetuating, but is created and maintained by election, generation after generation, of those who constitute the engineering profession. I know of nothing which can bring out the best in men better than an evidence of faith in their integrity and their ultimate sanity and ability, than the faith which Dr. Swasey displayed."

Mr. Coes in his message declared: "That Dr. Swasey's original conception was sound is borne out by the character and quality of the work done by the Foundation, and by the character and quality of the men active in its work. The work speaks for itself.

"That the Foundation can do greater work, be a greater force in the advancement of the engineering profession and for the good of mankind is not questioned by those infused with its ideals, aims, and objectives. As time goes on, it is my considered judgment that many of its objectives will be attained."

This Month's Authors

W. A. SHEWHART, in charge of fundamental quality engineering for the Bell Telephone Laboratories, is author of a well-known book bearing on this subject entitled "Economic Control of Quality of Manufactured Product." He is chairman of the Committee on the Development of Statistical Applications in Engineering and Manufacturing, sponsored jointly by the A.S.M.E. and three other societies. In 1932 he was invited to give a series of lectures at the University of London on the rôle of statistical method in industrial standardization. At that time, through the cooperation of the A.S.M.E., the A.S.A., and the A.S.T.M., he was instrumental in bringing about the formation of two committees on statistical techniques and quality control, one sponsored by the British Standards Institution and the other by the Deutscher Normenausschuss. He is an active member of several engineering committees on standardization and economics, and a member of numerous societies devoted to statistics, economics, physics, and mathematics.

Arthur M. Greene, Jr., dean of the School of Engineering at Princeton University since 1922, is a member of the A.S.M.E. Research Committee on the Thermal Properties of Steam.

His brief historical study of steam-table research in this country was presented at a dinner in connection with the Third International Conference on the Properties of Steam held recently in New York City. Dean Greene has been teaching in engineering colleges since his graduation from the University of Pennsylvania in 1894. He has served at Drexel Institute, University of Pennsylvania, University of Missouri, Rensselaer, and Princeton. He is the author of many books on the steam engine, pumping machinery, heating and ventilation, and refrigeration. The portraits of the distinguished engineers used in connection with Dean Greene's paper represent some of those who published steam tables in this country prior to 1921. A complete "gallery" could not be obtained, and information relating to existing portraits of Nystrom and Buel, particularly, would be appreciated.

Theodore Henry Brown, professor of business statistics at the Graduate School of Business Administration, Harvard University, has taught mathematics, astronomy, nautical science, economics, and business statistics in Yale, Brown, Columbia, and Harvard Universities. He is author of three books, "Problems in Business Statistics," "Laboratory Handbook of Statistical Methods," and "Statistical Analysis," and of numerous articles. He is also adviser to certain commercial and financial concerns, and is a member of statistical, economic, astronomical, mathematical, and cost-accounting societies.

George W. Kelsey, president, G. W. Kelsey & Co., New York, marketing counselors, was graduated from Stevens Institute of Technology in 1921, following which he served for a year and a half with Emerson Engineers, industrial counselors of New York City. For five years he conducted classes in shop organization and management for the Rutgers Extension Division at the Tide Water Oil Co., Bayonne, N. J. In 1930 he became manager of the molded-graphite products division of the Joseph Dixon Crucible Company, of New Jersey, after which he founded the organization of which he is now president.

Virgil M. Palmer, engineer of industrial economy at the Eastman Kodak Co., Rochester, N. Y., since 1916, was graduated from the Massachusetts Institute of Technology, in 1903. Following four years of service with the Pope Manufacturing Company, manufacturers of automobiles and bicycles, he was successively with the Smith Automobile Co., Topeka, Kans., the Selden Motor Vehicle Co., Rochester, the Selden Axle Co., Wilkes-Barre, Pa., and the U. S. Motor Co., of New York. In 1913 he began his service with the Eastman Kodak Co., where, until 1916, he was connected with the purchasing department.

Phillip A. Kinzie, whose description of the hydraulic valves and gates for Boulder dam is concluded in this issue, is a native of Denver. He was chief engineer of the Leyner Tractor and Manufacturing Company, of Denver, Colo., when he left, in 1920, to enter the Bureau of Reclamation. At present he is senior engineer in the mechanical-engineering section of the Bureau, in charge of the design of the equipment described in his paper.

R. E. W. Harrison, chief, Machinery and Agricultural Implement Division, Department of Commerce, was born and educated in England where his early designing and industrial experience was acquired. In 1923 he joined the engineering staff of the Cincinnati Grinders, Inc., Cincinnati, Ohio. At present he is secretary of the A.S.M.E. Machine Shop Practice Division, in which capacity he prepared the report of progress in that field.

Finding Work

AS ANNOUNCED last month, the article "Finding Work," by Samuel S. Board, that was published in the November issue of MECHANICAL ENGINEERING, has been issued in pamphlet form ($5^1/_4 \times 7^3/_4$ in.). Copies may be obtained by addressing the Publications Sales Department, A.S.M.E., 29 West 39th Street, New York, N. Y. The prices are: single copies, ten cents; 100 copies, $9; 200 copies, $16; 300 copies, $21; 400 copies $24, and 500 copies $25.

Bibliographies on Feedwater

IN SEPTEMBER, page 576, announcement was made of a bibliography on boiler feedwater and related subjects that had been prepared by the Joint Committee on Boiler Feedwater Studies and deposited for reference in the Engineering Societies Library, New York.

In acknowledging receipt of the bibliography, Harrison W. Craver, director of the Library, called attention to a number of others on these subjects prepared by the Library from time to time. The following tabulation gives essential facts relating to these searches. The "costs" given are the costs of making copies.

Search No.	Cost	No. of References	Subject and years covered
2851	$6.50	88	Treatment of boiler feedwater, 1897–1919
314	1.00	19	Distilling water for use in boilers, 1870–1907
3509	1.00	15	Degassing boiler feedwater, 1920–1921
4582	3.00	51	Soda-ash feedwater treatment, 1903–1922
4591	4.00	75	Use of soda ash in water softening, 1883–1911
4592	2.00	27	Use of sodium aluminate in water softening, 1899–1930
4538	2.50	42	Use of phosphates in water softening, 1849–1923
1393	1.50	17	"Luminator" water treatment, 1910–1913
4491	1.50	22	Use of barium carbonate in water treatment, 1859–1929

The Engineering Societies Library is constantly making searches on specific subjects from which such bibliographies as those tabulated result. Engineers wishing to make use of this service that the Library is able to render should communicate with Dr. Craver.

Proceedings of Eighth Oil-Power Conference Available

THE Proceedings of the Eighth Oil Power Conference held in conjunction with the Seventh National Meeting of the Oil and Gas Power Division of the A.S.M.E. last June at State College, Pa., has been published in a volume of 142 pages, copiously illustrated, by The Pennsylvania State College.

The Proceedings contain the following papers: "The Ex-Cell-O Fuel Pump," by C. R. Alden; "Cylinder Bore Characteristics and the Honing Process," by K. W. Connor; "Wear of Piston Rings and Liners Influenced by Design of Rings," by W. G. G. Godron; "Diesel-Electric Pipe-Line Pumping Stations," by L. M. Goldsmith; "The Minimum Regular Discharge of Jerk-Pump Fuel-Injection Systems," by Theodore B. Hetzel; "Recent Developments in Diesel-Engine Fuel Testing," by T. B. Rendel; "Penetration of Oil Sprays in Dense Air," by P. H. Schweitzer; "Diesel Engines of Light-Weight, High-Speed, and High-Mean Effective Pressure," by C. D. Treiber. The papers are supplemented with interesting discussions that followed the presentation of the papers.

The volume can be obtained from The Pennsylvania State College for 75 cents per copy.

E.C.P.D. Annual Meeting

THE second annual meeting of the Engineer's Council for Professional Development was held at the Engineering Societies Building, New York, N. Y., October 23, 1934. C. F. Hirshfeld was reelected chairman of E.C.P.D.

Chairmen of the four standing committees were reelected, as follows: R. L. Sackett, Committee on Student Selection and Guidance; Karl T. Compton, Committee on Engineering Schools; Robert I. Rees, Committee on Professional Training; and Conrad N. Lauer, Committee on Professional Recognition.

Reports of the four committees were presented, and an Information Committee was established under the chairmanship of H. C. Parmelee, of New York.

Further details of the work of the E.C.P.D. will be reported in a later issue.

Wood Industries Meeting

THE A.S.M.E. Wood Industries Division held its national meeting in Camden, N. J., October 23 and 24, under the auspices of the Philadelphia Section. The meeting opened on Tuesday morning with a visit to the plant of the R.C.A. Victor Company, of unusual interest because of the efficient handling and production methods in the manufacture of radio cabinets.

Technical sessions were held during the afternoon and evening at the Walt Whitman Hotel. During the afternoon Prof. P. T. Norton, in a paper entitled "Economics of Replacement of Manufacturing Equipment," gave his experiences in the southern woodworking plants. C. L. Babcock led the discussion with some interesting examples of replacement

of woodworking equipment. R. H. McCarthy presented a paper on the "Economic Loading of Exhaust Fans." Copies of Mr. McCarthy's paper are available in offset form. The remainder of the session was given over to an informal discussion of woodworking progress.

At the evening session the discussion centered on "Economic Lot Sizes in the Manufacture of Woodworking Products," a paper which was also presented by Professor Norton. The discussion was led by R. H. McCarthy, who told of the experiences of the Western Electric Company in this field, and showed two simplified charts that had been worked out to eliminate calculations. One of them was in the form of slide rule. The session closed with a lecture on termites given by H. B. Carpenter, who illustrated his remarks with unusual slides and films.

Wednesday morning was spent in visiting the Camden Vocational School and the plant at Tacony, Pa., of Henry Disston & Sons, where the visitors were guests of the company at luncheon. The afternoon session was held in Philadelphia, where, at a joint session with the American Foundrymen's Association, the subject of modern pattern-making practise was discussed. Paul H. Bilhuber presided.

Honored by Marquette

WORD has been received that Marquette University conferred the honorary degree of Doctor of Science on Arthur Simon, of Milwaukee, Wis., member, A.S.M.E., on June 13.

Highway Research Board to Meet December 6 and 7

MEMBERS of The American Society of Mechanical Engineers are invited to attend the annual meeting of the Highway Research Board of the Division of Engineering and Industrial Research, National Research Council, to be held at the Council Building, 2101 Constitution Ave., Washington, D. C., December 6 and 7. The preliminary program contains such topics as highway transportation economics, tractive resistance, highway design, low-cost roads, materials and construction, maintenance, and traffic. Buffet luncheons will be served both days at the Council building and there will be an informal subscription dinner on December 6 at the Washington Hotel.

Porter H. Adams Inaugurated

PORTER HARTWELL ADAMS, member, A.S.M.E., was inaugurated on October 22, as the sixteenth president of Norwich University, Northfield, Vt. The American Society of Mechanical Engineers was represented at the inauguration by an official delegate, Joseph B. Johnson, of the Bryant Chucking Grinder Company, Springfield, Vt., honorary vice-president.

Engineering Foundation Elects Officers

AT A MEETING of the Board of the Engineering Foundation the following were elected to fill the unexpired portion of terms of members of the Board ending on February 21, 1935:

Chairman; Harry P. Charlesworth, American Institute of Electrical Engineers; assistant chief engineer, American Telephone and Telegraph Company, New York, N. Y.

First Vice-Chairman: D. Robert Yarnall, The American Society of Mechanical Engineers; member of firm, Yarnall-Waring Company, Philadelphia, Pa.

Second Vice-Chairman: Edwards R. Fish, member-at-large; The American Society of Mechanical Engineers; Hartford Steam Boiler Inspection and Insurance Company, chief engineer, Boiler Division, Hartford, Conn.

Representative on National Research Council: Harry P. Charlesworth.

Additional member of Executive Committee: Otis E. Hovey, American Society of Civil Engineers; also member, A.S.M.E., consulting engineer, American Bridge Company, New York, N. Y.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after December 26, 1934, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

NEW APPLICATIONS

ALDRICH, W. H., Cleveland, Ohio
ALLEN, MAJ. MICHAEL H. P., Johannesburg, South Africa
BEDINGER, ALBERT F. G., Knoxville, Tenn. (Re)
CADWALLADER, LEWIS W., Washington, D. C.
COLE, SIDNEY I., Chicago, Ill.
CORK, LINN C., Birmingham, Ala.
DAFOE, LESLIE R., Seattle, Wash.
GODFREY, WILLIAM G., Buffalo, N. Y.
GRANT, WILLIAM W., Southbridge, Mass. (Rt)
HALL, H. ELMER, Cambridge, Mass.
HATCH, THEODORE F., Boston, Mass.
HOLLERAN, DOMINIC J., Irvington, N. J.
HOVGAARD, PROF. WILLIAM, Brooklyn, N. Y.
HUNT, NATHAN C., Salem, Ohio
IRVIN, EARL HARRISON, Brooklyn, N. Y.
KEIL, ELMER F., Buffalo, N. Y.
KEVITT, CHESTER B., Passaic, N. J.
KINGSBURY, R. W., Jacksonville, Fla.
KISS, NICHOLAS, New York, N. Y.
MARTYN, WILLIS S., Orchard Park, N. Y. (Rt & T)
MAZAIKA, JOHN, Maspeth, L. I., N. Y.
MCHUGH, AUSTIN G., Youngstown, Ohio
MCQUESTON, FRANCIS W., Angola, Ind.
OYEN, ERLING O., Youngstown, Ohio
PARKER, PROF. E. B., Pullman, Wash.
PERKINS, PROF. HAROLD C., Ithaca, N. Y.
RICH, GEORGE R., Kansas City, Mo.
SHIRTLEY, S. L., Sydney, New South Wales
UZDAVINIS, JOSEPH P., Brooklyn, N. Y.
WARD, LESTER D., Los Angeles, Calif.
WENDEL, D. P., Buffalo, N. Y.
WRIGLEY, JAMES BRENT, Tulsa, Okla.
YAMAMOTO, T., Cambridge, Mass.

CHANGE OF GRADING

Transfers from Associate-Member

HAGUE, C. K. F., New York, N. Y.
KEENAN, JOSEPH H., Brookline, Mass.

Transfers from Junior

DOWNING, JOHN CHARLES, Kenmore, N. Y.
FRIEDEBERG, SOLON E., New York, N. Y.
GAGG, R. F., Fair Lawn, N. J.
HOLMES, JOSEPH A., Chicago, Ill.
JACOBUS, PROF. DAVID D., Hoboken, N. J.
JAMISON, GEORGE S., Glens Falls, N. Y.
JOHNSON, WILFRID E., Schenectady, N. Y.
KAHN, LEOPOLD, New York, N. Y.
KIRLOSKAR, S. L., Kirloskarvadi, India
KUTTLER, JOHN B., Roselle Park, N. J.
LOSSON, WESLEY L., Paterson, N. J.
LUNDSTROM, C. BRYNOLF, Little Falls, N. Y.
MITCHELL, JOHN C. W., Bloomfield, N. J.
QUEISSER, HERBERT W., Berlin, Germany
SMITH, JOHN S., Wellsville, N. Y.
THOMPSON, THEODORE E., Niagara Falls, N. Y.
WARD, PROF. N. F., Berkeley, Calif.
WATSON, RAYMOND H., Kansas City, Mo.

A.S.M.E. Transactions for November, 1934

THE November, 1934, issue of the Transactions of the A.S.M.E. contains the following papers:

A New Theory for the Buckling of Thin Cylinders Under Axial Compression and Bending (AER-56-12), by L. H. Donnell

The Design and Performance of an Axial-Flow Fan (AER-56-13), by Lionel S. Marks and John R. Weske

Further Experiments on the Variation of the Maximum-Lift Coefficient With Turbulence and Reynolds' Number (AER-56-14), by Clark B. Millikan

Collapse by Instability of Thin Cylindrical Shells Under External Pressure (APM-56-20), by Dwight F. Windenburg and Charles Trilling

Fluid-Meter Nozzles (FSP-56-14), by B. O. Buckland

The Test Performance of Hudson Avenue's Most Recent Steam-Generating Units (FSP-56-15), by P. H. Hardie and W. S. Cooper

Flow Distribution in Forced-Circulation Once-Through Steam Generators (FSP-56-16), by H. L. Solberg, G. A. Hawkins, and A. A. Potter

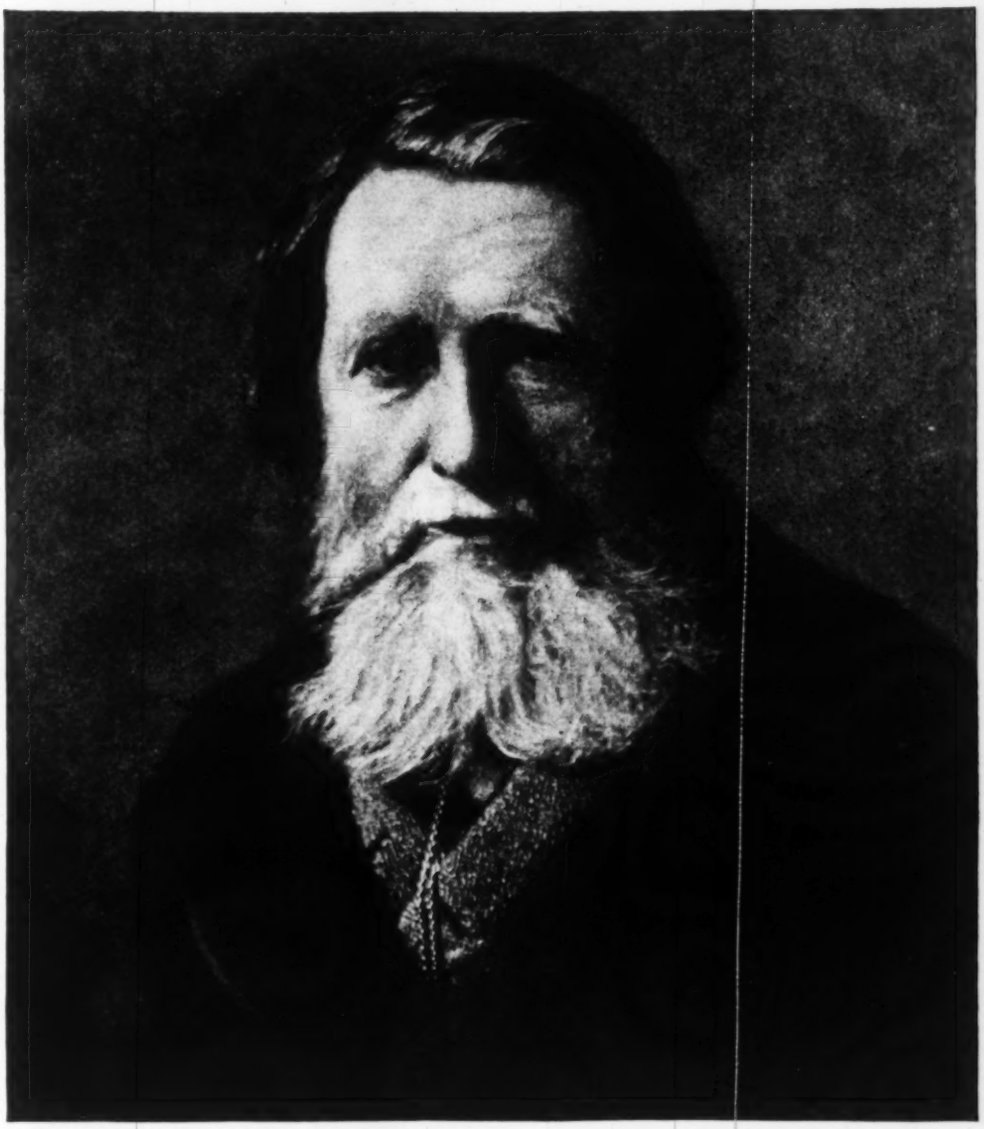
Manufacture of Large Seamless Steel Tubes by the Tschulenk Forge-Rolling Process (IS-56-3), by Arthur J. Herschmann and Leopold Tschulenk

Budgeting an Industrial Enterprise (MAN-56-2), by Walter Rautenstrauch

Current Practise in Surface Broaching (MSP-56-1), by Joseph Geschelin

Air Flow in Fan-Discharge Ducts (PTC-56-2), by Lionel S. Marks.

• • • There is hardly anything in the world that some man cannot make a little worse and sell a little cheaper, and the people who consider price only, are this man's lawful prey. —**RUSKIN**



● Published solely in the interest of forward-thinking in steam power equipment practice—for it is a precept of The Superheater Company and The Air Preheater Corporation, 60 East 42nd Street, New York, that neither maker nor buyer of equipment can long profit where the highest development in the art is not expressed in the product—and where a constant pressure is not exerted by both parties to bring it to a still higher development. The urge for product improvement must be mutual, that profit may be mutual.

A-932

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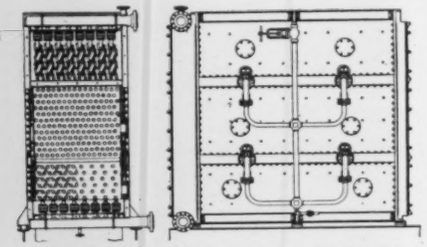
New Design of Economizer

The new Elesco economizer, manufactured by The Superheater Company, 60 East 42nd St., New York, N. Y., incorporates many new features which are responsible for an unusually high heat-transfer rate and operating efficiency.



The heat-transfer elements consist of a series of Elesco bifurcated finned tubular units. These bifurcated units, together with the return bends forged from the ends of the tubing, permit close spacing of economizer surface which provides the highest heat-transfer rate. The Elesco bifurcated units comprise two tubes integrally forged together at their ends to form a single, rather than two terminals. This substantially reduces the number of joints and the attendant possibility of leaks. Another important precaution against joint leakage is the use of 3-stud flanges for connecting the series of units. The economizer elements are contained in a casing with hinged doors at the ends, which permit easy access to the elements.

For special applications where internal cleaning and inspection of the elements are unnecessary units of continuous loops, but otherwise of the same general construction, are employed. The Elesco economizer is built for both natural and induced draft and is applicable to all sizes of boilers.

Geared-Head Turbo-Blowers

A new, exceptionally compact Centrifugal Compressor (Turbo-Blower), making use of a gearmotor, is introduced by Allis-Chalmers Mfg. Co., Milwaukee, Wis. By using the gearmotor for speed increase, the blower can run at higher than motor speeds, thus reducing dimensions and improving performance. Pressures from .75 lb. G. to 3.0 lb. G. are developed, the volumetric capacities corresponding to motor outputs from 3 to 30 hp. The units have application for foundry cupola blowing, oil and gas fired furnaces, pneumatic conveying, agitation and aeration, and for similar moderately low pressure air or gas supply services.

RATE $1.25 PER LINE

Minimum insertion ten lines, including one line heading free; twenty lines or more, two line heading free. Maximum insertion in any one issue, fifty lines. Text matter averages seven words to the line. Illustration cuts not exceeding one column wide may be used and are charged for by the number of lines in depth.

Announcements accepted will be placed in the first available issue, space permitting. A given announcement may be inserted only once.

Unusual Use of Plykrome

Notable among the numerous installations of Plykrome made during the past year is that in the Milwaukee Sewage Disposal Plant, where this new stainless clad steel is being fabricated into an 1800 foot line of pipe ranging from two feet to five feet in diameter.

Plykrome, a unique stainless clad steel, produced exclusively by Illinois Steel Company, 208 S. LaSalle St., Chicago, Ill., has been widely adopted for corrosion resisting installations, but this is the first instance in which it has been used to reduce the friction of compressed air passing through a pipe.

It was desirable to use a metal which had a low internal coefficient of friction, and which, further, would not be subject to corrosion and hence to a gradual accumulation of scale, rust, or dirt which would tend to increase friction through years of operation. Plykrome met all requirements. It could be readily fabricated with its stainless surface on the interior of the pipe, where it would effectively resist corrosion for an indefinite period.

The fabrication of the Plykrome has been in the hands of the Cream City Boiler Company of Milwaukee. Arc welding has been used for fabrication as well as for the field welding involved in the installation of the duct. The Plykrome used is one-quarter inch thick with an inside stainless veneer of USS 18-8 Stainless Steel. The pipe has been fabricated in sections of approximately 54 feet in length. Each section is made of nine plates of Plykrome. A welding speed of approximately 50 feet per hour has been maintained.

Nine of the plate shells thus formed are welded together to make the 54-foot sections of pipe. The circumferential joints are butt welds made after the plates had been sheared square and placed with a $^3/_{32}$ inch gap between edges. About 1325 feet of the pipe is 5 feet in diameter. The balance ranges from 24 inches to 48 inches. The entire project requires approximately 315,000 pounds of Plykrome—the largest single installation of stainless clad steel ever made.

Goodrich Perfects Endless Belt

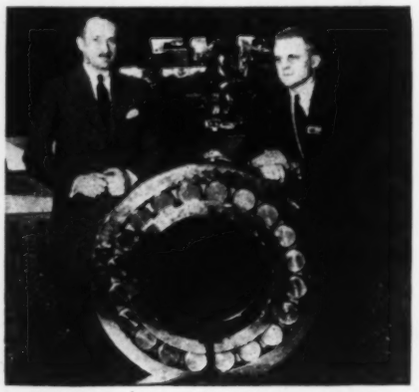
A revolutionary method of making belts endless has been perfected by Fred G. Skeyhan, a member of the technical staff of The B. F. Goodrich Company, Akron, Ohio, according to a current announcement.

The improved construction, known as the "Plylock Belt Joint" is said to overcome a difficulty which has been experienced to some degree with all step belt joints—a tendency of the outside seams to open up during severe service.

Skeyhan conceived the idea of imbedding or counter-sinking the seam below the surface of the belt in such a position as to relieve the seam from strain and shield it from wear or windage. This protection is made possible by a thick cushion of rubber reinforced with bias fabric which is permanently vulcanized into position.

Although the Plylock Belt Joint has been used successfully in the field by several companies during the last year or two, only recently was it definitely decided to offer it for public use. Patents for the process have been applied for by Goodrich who will license agents, jobbers, and users to make the Plylock Belt Joint themselves after Goodrich representatives have given them complete instructions. The improved construction will, of course, be featured in all Goodrich factory-built endless belts.

1,500-lb Roller Bearing

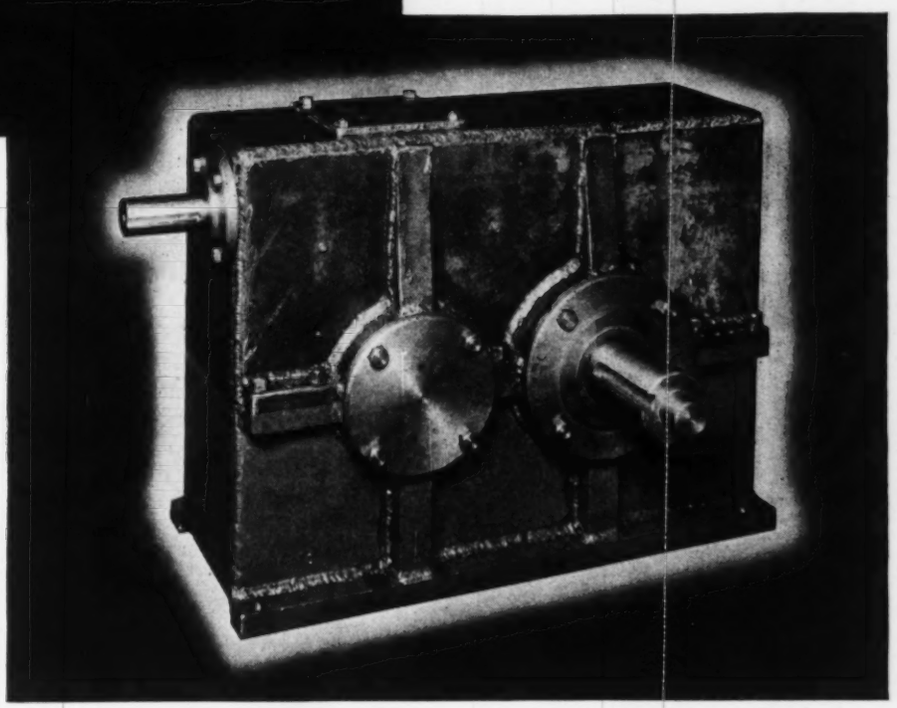


This 1,500-lb. self-aligning roller bearing is the answer of SKF to industry's demand for large heavy-duty bearings, say Messrs. R. H. DeMott, sales manager (left) and Robert C. Byler, advertising manager (right), SKF Industries, Inc., Front Street and Erie Avenue, Philadelphia, Pa. It is a type of bearing used in giant rolling mills, Fourdriniers, oil field machinery, crushers, pulverizers, wherever stamina is desired.

But there never was a single bearing type, not even an SKF, that could perform the multitude of varied tasks to which antifriction bearings are assigned today. Turning wheels—all turning things—are different. And for that reason there are SKF bearings as small as a dime to answer problems of SPEED that vary perhaps from 50 R.P.M. to 50,000 R.P.M., SKF bearings that meet problems of LOAD that vary from the ability to sustain a feather's weight up to tremendous crushing stresses of thousands of tons, SKF bearings that fill all requirements for both SPEED and LOAD at the same time.

And the SKF ball, the roller, the deep groove, and the thrust are prototypes of more than 1,200 bearings. So SKF offers a series of bearings and related bearing equipment such as housings, hangers and antifriction equipment, designed for practically every bearing purpose. If you have a bearing problem SKF engineers will gladly help you select from this array of equipment the Right Bearing for the Right Place.

A CASE



OF REDUCTION

in time and cost by "Shield-Arc" welding

Tuesday . . . a failure of the original cast case of this speed reducer shut down an entire manufacturing process. A week to ten days for a new pattern plus added days for casting a stronger case, reported the equipment manufacturer.

In 40 hours half a ton of rolled steel plates and shapes were cut to size, assembled and *"Shield-Arc"* welded to form a stronger, stiffer speed reducer housing at a cost far less than a casting.

Friday . . . production was resumed.

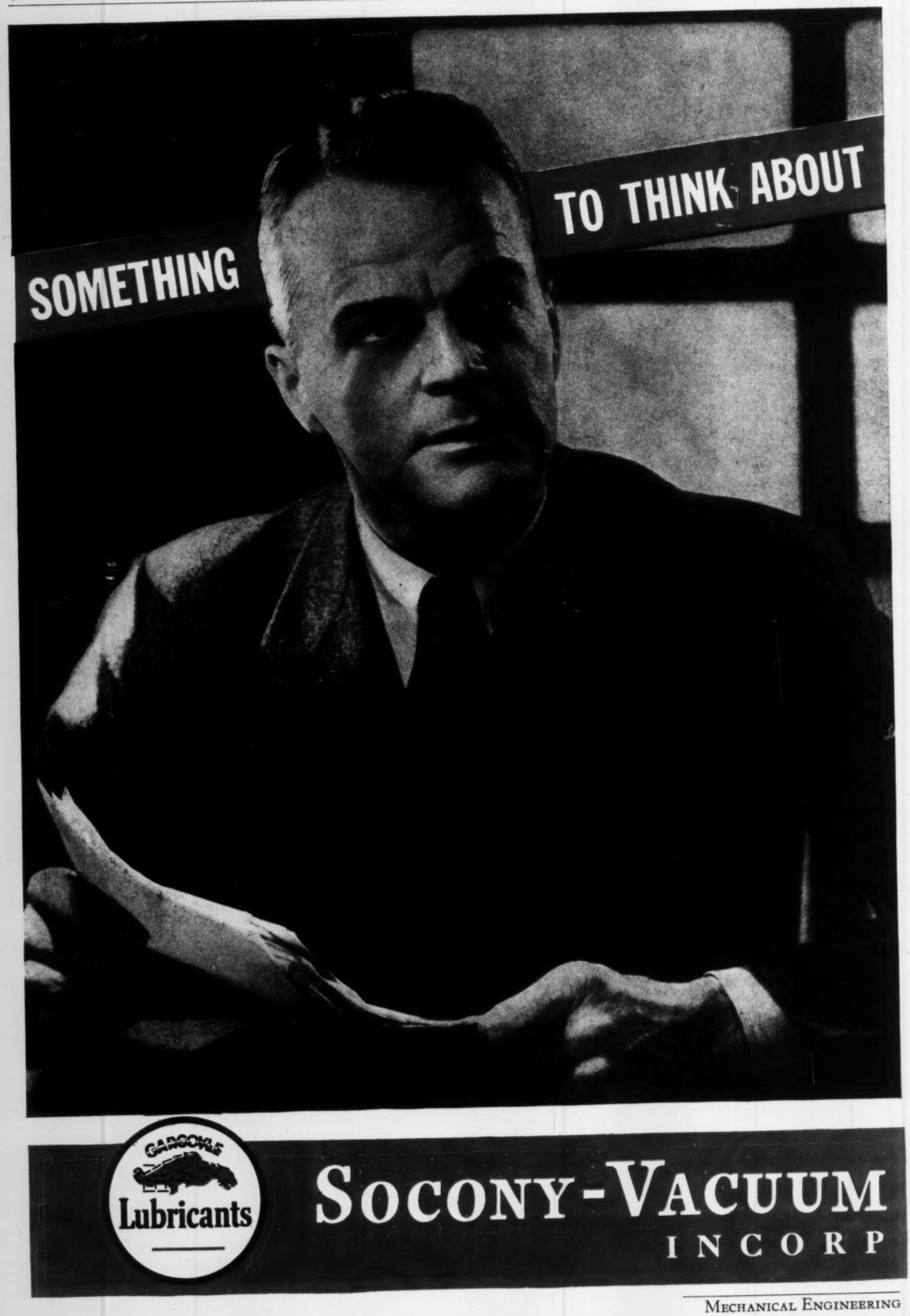
This is but one of hundreds of typical cases of time and money saved, as well as product improvement, effected by *"Shield-Arc"* welded steel construction of machines and machinery parts.

The speed reducer manufacturer, like many other machinery builders, took advantage of every possible saving by welding with a *"Shield-Arc"* welder. It allowed him to get the most out of welding—for *"Shield-Arc"* welds faster. Makes better welds. Uses less power. Puts more of the electrode into the weld.

Eleven distinctive features of the *"Shield-Arc"* welder make it give you more weld per dollar . . . and better welds. That's why more Lincoln welders are in use today than any other make. And why many are scrapping their old type machines for *"Shield-Arcs."* Find out how much *"Shield-Arc"* welders can save you. Ask The Lincoln Electric Company, Cleveland, Ohio. Largest Manufacturers of Arc Welding Equipment in the World.

W-89

LINCOLN "SHIELD-ARC" WELDERS


SOMETHING
TO THINK ABOUT
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Lubricants
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INCORP

Show a LUBRICATION PROFIT FOR 1935!

Savings in power... reduced maintenance... uninterrupted production... and less lubrication expense add up to a LUBRICATION PROFIT *for your plant*

CERTAINLY LUBRICATION PROFIT is worth the consideration of every plant executive who has any responsibility for the lubrication of his plant.

It is, for example, yielding $2,700 a year additional net income for a paper mill . . . $4,925 annually for a textile plant . . . $9,000 yearly in a rubber mill . . . $1,800 in a machine shop.

It frequently uncovers unsuspected possibilities for substantial savings in power . . . reductions in repair and maintenance . . . smoother production flow . . . lower cost of lubrication itself . . . in plants of every type.

These economies grow logically out of the methods, the knowledge and the facilities that Socony-Vacuum puts at the disposal of your plant staff. The fact that more new Socony-Vacuum customers than ever before are making use of them is but one definite indication of their effectiveness.

• • •

IF YOU BELIEVE that conditions this year warrant combing your business for every profit possibility, why not go into the lubrication profit idea with one of our lubrication engineers? Socony-Vacuum Oil Company, Inc., 26 Broadway, New York City.

OIL COMPANY
ORATED

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Number 3 of a series

MECHANICAL CATALOG NEWS

1935-36 EDITION Now Being Compiled

For information, address
The American Society of Mechanical Engineers
29 W. 39th St., New York, N.Y.

Short Stories About Firms who have abridged catalogs in the 1934-35 Edition

Babcock & Wilcox Co., 85 Liberty St., New York, N. Y. Since 1867, when the patent was granted for the original Babcock & Wilcox boiler, the history of the company has been one of steady growth and progress. The present company was incorporated in 1881, the year of the birth of the electric generating station. Boiler units are now built in all sizes, complete in every important respect, and other products of the company and its subsidiaries include process equipment, seamless tubular products, and refractories. The motive of the company has always been, and is, that of giving the best and most satisfactory service; of furnishing the best in ideas, information, material and workmanship; of justifying the faith of its customers.

New Departure Mfg. Co., Bristol, Conn. Any American who ever straddled a bicycle has a good word for New Departure Coaster Brakes. It has been a standard, dependable article since 1899. Eight years later New Departure engineers first sensed the approaching era of motor cars and the necessity for anti-friction devices. Production started in 1907 and this division has seen a phenomenal growth because every industry soon became ball bearing minded. So extensive are New Departure's present facilities that 125,000 quality ball bearings is the present daily plant capacity. Your bearing problems get expert attention here.

Abart Gear & Machine Co., 4837 W. 16th St., Cicero, Ill. Originally organized to manufacture precision cut gears, special speed reducers and gearing for those who require high grade products. Since then have added through purchase the Goodwill Tools, Patterns and Drawings of the Albaugh-Dover Mfg. Co., and continue to manufacture the complete standard line of Speed Reducers. Also maintain an engineering department at your disposal which can cope with any gearing or speed reduction problem you require.

C. O. Bartlett & Snow Co., 6450 Harvard Ave., Cleveland, Ohio. This concern is recognized in the United States and in many foreign countries for the high quality of its workmanship and the skill of its engineering accomplishments. This concern has won great prominence in the foundry industry, having engineered, constructed and installed complete sand reclaiming and sand reconditioning equipment, mold and finished casting conveyors, and other mechanical equipment in large and small steel, brass, aluminum, gray and malleable iron foundries, including installations in the giant Chevrolet and Buick plants. The company maintains an exceedingly competent engineering department and includes among its personnel experts in the fields covered by products of its manufacture, a completely equipped machine and spacious structural shops, that enables the prospective purchaser to concentrate the entire responsibility for the satisfactory design, construction and operation of a unit in one wholly competent organization.

Medart Co., 3504 DeKalb St., St. Louis, Mo. Nationally recognized as one of the foremost manufacturers of Power Transmission Machinery of all kinds. Established 1879 as the Medart Patent Pulley Co. The shops and foundry now occupy five city blocks in the City of St. Louis, Mo. This company also manufactures turned and polished shafting. Shaft Turning and Polishing Machinery in use in the majority of cold finishing steel mills in the country today has been built by this company. The St. Louis Shafting Mill of this company is one of the oldest in the United States. The products also include special machinery, alloy iron castings, and other specially engineered products for oil, textile, paper, chemical, and other industries. The first steel rim, steel arm pulleys made in the United States were made by this company.

Dayton-Dowd Co., Quincy, Ill. From a modest beginning a quarter of a century ago has grown the present extensive line of Dayton-Dowd centrifugal pumps, in single and multi-stage designs, for virtually every pumping service. Dayton-Dowd builds centrifugal pumps exclusively and is a completely integrated plant, having its own engineering department, pattern shops, iron and brass foundries, machine shops, assembly shops, and one of the most up-to-date hydraulic laboratories in the country. The line comprises centrifugal pumps only, from ¾" to 60" discharge. No other type of pump occupies their attention or facilities.

Hayward Co., 40–46 Dey St., New York, N. Y. Founded in March, 1897. One of the pioneers in the development of the grab bucket, both for digging and rehandling applications, it has perfected a line of equipment that includes every type of bucket for every service. Among the more popular Haywards are the Orange Peel Bucket in Standard, Heavy and Multi-Power designs, also the Three Bladed Orange Peel for handling rock, and the Dwarf Buckets and Midget Digging Machines, the Class "E" Clam Shell, better known as the Hayward Rehandling Bucket, the Class "K," which is The Hayward Digging Clam Shell Bucket; the Electric Motor Clam Shell Bucket for overhead crane service, and the Drag Line Bucket. The Hayward Line also includes Dredges, Traveling Derricks and Coal Handling Machinery, Cable Take-up-Reels and Counterweight Drums.

Pennsylvania Pump & Compressor Co., Easton, Pa. Has continuously maintained reputation for highest standards of design and construction. In air compressors and vacuum pumps, air cushioned valves and improved methods of control and regulation are outstanding features. In centrifugal pumps, thrust troubles virtually eliminated through opposed impellers and differential diameters of stage bushing, in multi-stage types; and by balancing port connecting two suction chambers at impeller inlet, in single stage types. Recent additions to products have been steam booster compressors and close coupled Penn-Motor Pumps, designed to meet varied fields of application.

American Screw Co., Providence, R. I. This business was established in 1838 and 1840 by two independent Rhode Island corporations, which united and were incorporated under the present title in 1860. The company is the pioneer, as well as the largest, among the survivors in its industry with large plants in Providence, and a branch, the Reading Screw Company, at Norristown, Pa.

Philadelphia Gear Works, Erie Ave. & G St., Philadelphia, Pa. Has manufactured Gears for nearly a half century, and was one of the pioneers in the design and construction of Speed Reducing Units for industrial purposes. Their recently constructed plant at Erie Avenue and G Street, Philadelphia, is one of the most modernly designed and equipped Gear Plants. This company's latest contribution to industry is the "Motoreducer," a unified, self-contained, compact, efficient combination of Electric Motor and Speed Reducer. This device requires no base plate or flexible couplings, etc. The Company also makes the well known Limitorque Motor Valve Operator.

Pulverizing Machinery Co., Roselle Park, N. J. One of the younger but now thoroughly established and successful concerns in the field. Executive offices, Research Department, and well equipped manufacturing plant are located at Roselle Park, N. J. Technical Sales representatives are located in large cities throughout the country. Has specialized in difficult grinding problems, in elimination of dust nuisance, etc., and has now some eight hundred of its patented "Mikro-Pulverizers," or special grinders, Disintegrators, Blenders, Dispersers, in use in the Chemical, Food, Mineral, and other industries.

Reliance Gauge Column Co., 5914 Carnegie Ave., Cleveland, Ohio. Organized in 1884 on the patenting of the Reliance float-operated water column, a whistle alarm for guarding boiler water levels. This company was one of the pioneers in its field and in recent years has been one of the leaders in the development of boiler alarms for high pressure. It now produces safety water columns, gauge cocks, and water gauges for pressures up to 2000 pounds, its Mica-sight water gauge being particularly notable in surmounting the limitations of glass in such devices. But the most important achievement of Reliance engineers has been the Reliance Monel Float, made by an original process, resulting in extraordinary buoyance and dependability.

Ohio Grease Co., 505–635 N. Spring St., Loudenville, Ohio. More than a quarter century ago this company introduced a successful grease for steam cylinder lubrication and are today recognized by many engine builders and operators as foremost in the field. They also manufacture a variety of high grade industrial and automotive lubricants.

Monarch Mfg. Works, Inc., Westmoreland & Salmon Sts., Philadelphia, Pa. Established November, 1916 (not incorporated); incorporated January, 1918, for the manufacture of spray nozzles, valves and strainers.

Powers Regulator Co., 2726 Greenview Ave., Chicago, Ill. Established in 1891 by William Penn Powers, succeeded by his sons, Fred W. Powers and Donald J. Powers, who are now actively engaged in the firm's management. The company has long been recognized as one of the leading manufacturers of control apparatus for regulating heating, ventilating, and air conditioning equipment. It is also widely known for its comprehensive line of regulators used to control industrial processes and the automatic mixing of hot and cold water. In addition to these products it also manufactures dial indicating thermometers, steam traps, pressure reducing valves, etc.

A USER WRITES

THE LAMSON & SESSIONS CO.
Manufacturers of
BOLTS - NUTS - COTTERS - CAP SCREWS
CLEVELAND, O.

November 5, 1934

American Society of Mechanical Engineers
29 West Thirty-Ninth Street,
New York City, N. Y.

Gentlemen:—

I received my copy of The Mechanical Catalog and I will place this catalog in our Engineering Department at our main plant.

I find the Mechanical Catalog very valuable and it is referred to continually for information leading to purchase.

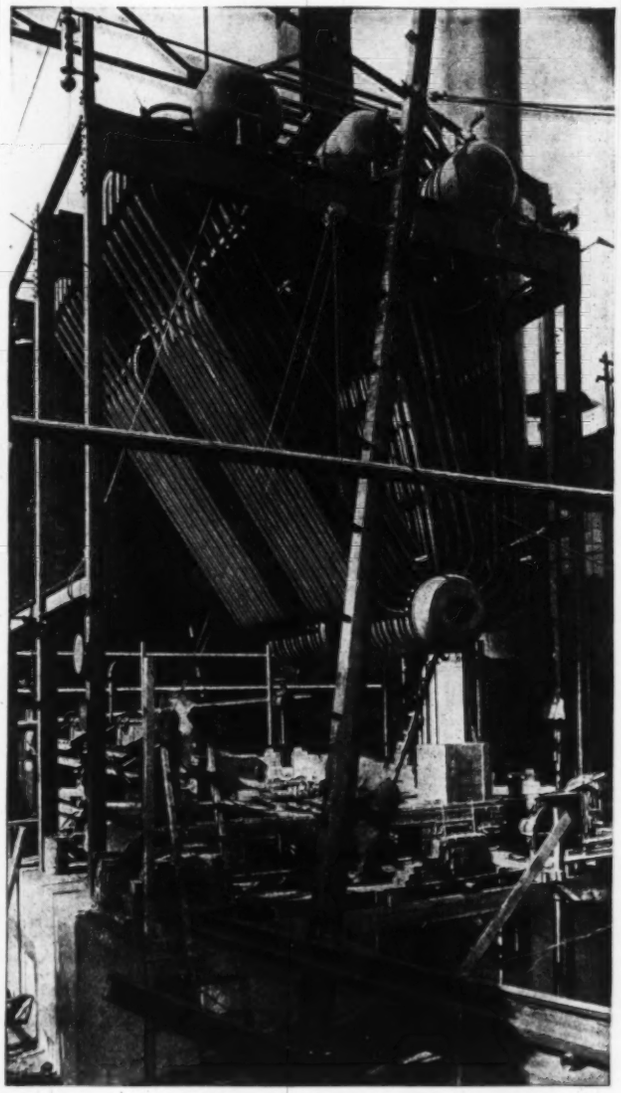
Yours very truly,

THE LAMSON & SESSIONS CO.
(signed) A. E. Buelow
Chief Engineer

The only specialized reference annual for the buyer and specifier of mechanical equipment and engineering materials—contains the essential data of outstanding firms whose products are of interest to engineers and Engineer-executives.

C-E BENT TUBE BOILER--Design VA

. . . reduced turbulence . . . drier steam . . . equalized water level under changing loads



Above is shown side view of C-E Bent Tube Boilers Design VA, now being installed at the Trenton, N. J. plant of the Thermoid Rubber Company. Note that alternate rows of tubes in the first and second banks connect respectively with the front and middle drums, and also arrangement of circulator connections. The effect of these important design features is described briefly in the text.

The C-E Bent Tube Boiler, Design VA, was brought out by Combustion Engineering to meet a demand for a boiler that could be operated over a wide range of output under rapid and extreme load swings, with less turbulence in water level in the respective drums, and with drier steam than was obtained with earlier designs.

These desirable operating characteristics have been effectively obtained by providing for alternate rows of tubes in the front bank to connect respectively with the front and middle drums; alternate rows of tubes in the second bank being similarly connected. Steam liberation from the front tube bank, which does the most work, is thus divided between the two drums. Also important is the fact that the most active tubes discharge steam into the drums at a point above the water line. Separate steam circulators deliver steam from these drums to the outlet drum, and water circulators connect the middle and rear drums to equalize water level when the load changes. In consequence, turbulence of the water in the drums is minimized, oscillations in water level are reduced and less water is carried over into the steam.

Although this new design has been on the market a relatively short time, C-E Design VA Boilers are today serving many prominent industrial concerns, public utilities and institutions. At the left are shown two new units now being installed in the Trenton, N. J., plant of the Thermoid Rubber Company. Scrutiny of these views will show the tube arrangements referred to above.

Data on these and other C-E boilers, firing equipment, heat recovery apparatus and complete steam generating units will be supplied on request. Also the counsel of C-E engineers is available to you and your consultants without obligation. Let us help you to meet your steam requirements in a manner that will be of maximum economic advantage to you.

COMBUSTION ENGINEERING COMPANY, INC.

200 MADISON AVENUE - - NEW YORK, N. Y.

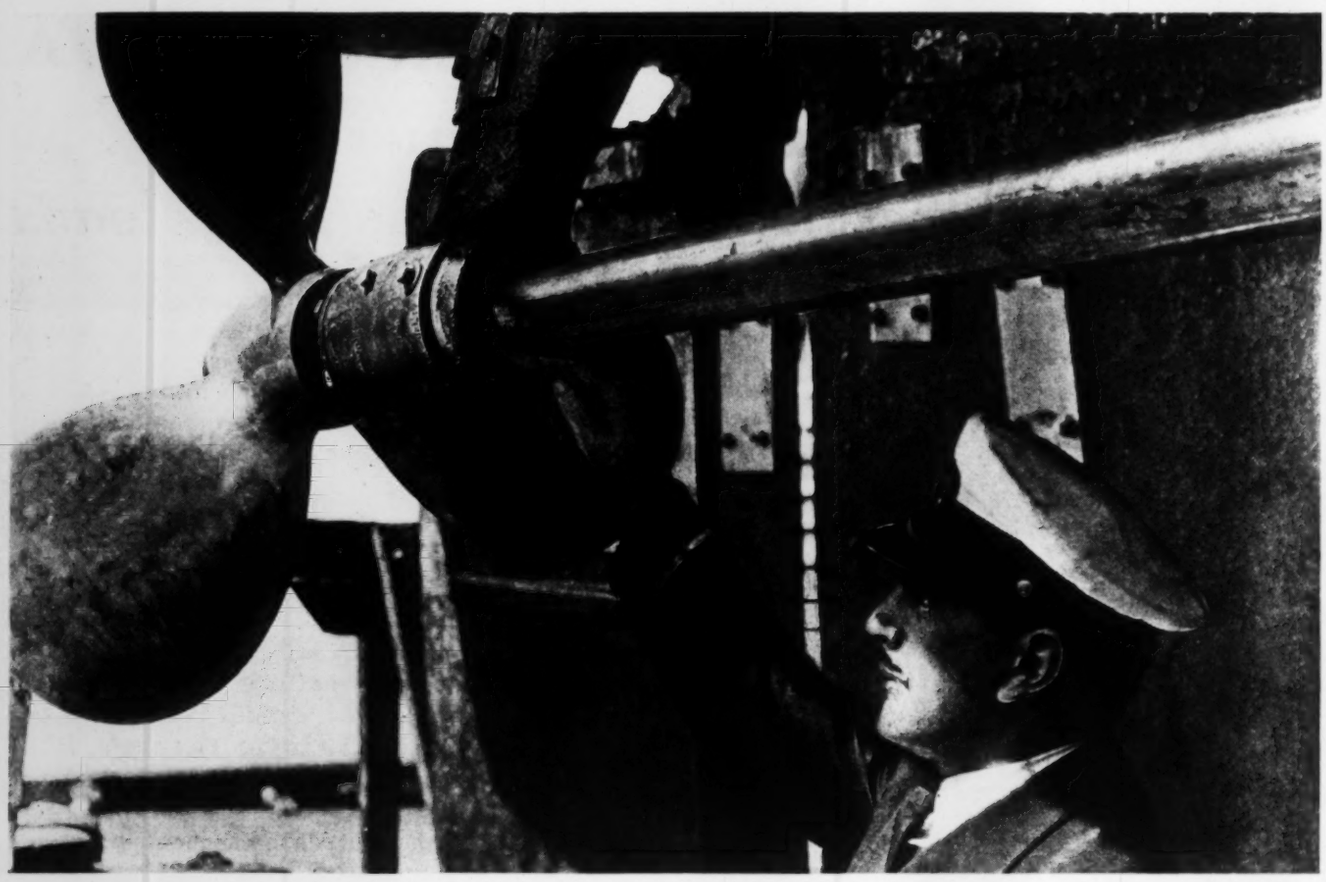
Canadian Associates

Combustion Engineering Corp., Ltd., Montreal

A-195a

BOILERS — STOKERS — PULVERIZED FUEL SYSTEMS — FURNACES — AIR HEATERS — ECONOMIZERS

Complete steam generating units of standard overall design or comprised of any combination of boiler and firing equipment



RUBBER Sails The Seven Seas

THERE *is* a sea monster. Since the early days of steamships it has attacked and destroyed propeller shafts and bearings. Its name is *abrasion*. Propeller shafts, of course, work under water, which always contains some sand and grit. These hard particles flow in with the water, are ground between bearing and shaft, and destroy the toughest metal or wood.

An engineer came to Goodrich with an idea for the use of rubber. Bearings were made of soft rubber with longitudinal grooves. When any foreign matter enters this bearing, the rubber depresses and lets it roll harmlessly into one of the grooves, where it is washed out and away.

This is the Goodrich Cutless Rubber Bearing, which now sails the seven seas, and lasts (and makes propeller shafts last) five to ten times as long as the former bearings of wood or metal. Here is only one of the countless new uses for rubber, made possible by the new properties Goodrich engineers have given this adaptable material.

If your product or process needs silence, remember that rubber absorbs vibration and noise. If corrosion troubles you, rubber can be made to resist acids, oils, heat. If wear is a factor, rubber can stand abrasion, endless flexing, terrific pressure. If new forms or colors or textures would help your product's sales, rubber can supply them.

New deals and new competition call for new improvements in products and their making. Modern rubber is a *new material,* with infinite new possibilities. Let Goodrich show you what they are. The B. F. Goodrich Co., Mechanical Rubber Goods Division, Akron, Ohio.

Goodrich

ALL *products problems* IN RUBBER

A.S.M.E. GUIDE TO

NATIONAL POWER SHOW

Eleventh National Exposition of Power and Mechanical Engineering

Grand Central Palace, New York, N. Y. December 3rd to 8th, 1934

THE "A.S.M.E. Guide" to the National Power Show is again presented by MECHANICAL ENGINEERING and contains a "List of Exhibitors" which appears on page 11 and which has been submitted to the Management of the Exposition for final checking. Its accuracy in detail is not guaranteed because of inevitable changes between the date of going to press and the opening of the Show. In this list the numbers of booths occupied are given and by referring to the floor-space diagrams shown on page 13, a user of the Guide at the Show can readily locate any booth in which he is interested. A.S.M.E. members are especially invited to visit the A.S.M.E. Booth (No. 80) on the main floor near the front entrance, where full information regarding A.S.M.E. activities and publications will be available.

This year's show will draw an attendance unprecedented in previous years, because of the unusually wide range of major equipment and accessory units which will be exhibited. Research progressively carried forward while production was at a standstill has accomplished results which the average engineer has not yet had opportunity to assimilate. The Power Show will reveal the latest developments in every phase of power economy and machine efficiency. From the generation of power, through its transmission, in every phase up to the final machines which manufacture the products, literally in every phase of mechanical industry, the pageant of mechanical engineering progress will be complete.

An Engineering Conference Bureau under the Chairmanship of David Moffatt Myers, a member of the Advisory Committee, will provide a place where visitors may discuss their engineering problems with engineers apart from a selling atmosphere. This provides a means of contact between the engineer and visiting capitalist, industrialist or professional from other lines, who seeks trustworthy information upon topics related to the objects or purposes of the exposition whether they are included in exhibits or not. The Committee will be comprised of leaders in their respective fields as well as having available the services of a corps of Junior Engineers, members of the A.S.M.E.

The Time of the Exposition is particularly appropriate. Following years of reduced production and accompanying machine obsolescence, present stimulated production compels equipment replacement and an interesting amount of new machine installation. Thousands, interested in these trends, make it a point to visit the Exposition, not only because it is interesting and educational, but particularly because they respond to its value as a setting in which comparisons can so readily be made, in one location, in brief time. Responsible for engineering design and for mechanical equipment purchase, engineers can here weigh the comparative values of products of an established class with those of potential successors.

Power generation and distribution, engines and auxiliaries, electrical equipment and elevators, pumps, air compressors, refrigeration equipment—in every class, exhibits are being made to show the most valuable and the newest improvements. Presented in addition, there will be innumerable auxiliary equipment and materials of interest. Among these, to name only a few, are piping and valves, mechanical stokers, materials handling machinery, fire protection equipment, and ceramic materials including fire brick and cements.

The most comprehensive and advanced presentation of new ideas in major fields of mechanical engineering such as prime movers, transmission and fuel economy, will be supplemented by a variety of industrial specialties—each a minor exposition in itself.

Fuels of every variety are involved as well as a wide range of apparatus, ranging from fuel-handling devices and electric service lines, to engines, motors, and innumerable electrical and mechanical accessories.

The power transmission section, showing a wide variety of equipment and the innumerable accessories, is extensive. Silent and roller chain drives, flexible couplings, friction clutches, free wheeling clutches, will be featured in an exhibit designed to couple cost saving transmission with improved efficiency. Transmission problems in terms of the factory of the new era will be aided by an unusually large section devoted to shaft hangers, blocks, couplings,

gears, sprockets, speed reducers, motor reducers and valve controls.

The story of instruments, it has been said, is "never old and never told." Designed to improve fuel economy, a large variety of recording and indicating precision instruments will be shown. Instruments will be shown to measure steam developed at the source, and also the amounts used by various departments in a manufacturing plant.

In the field of piping, amalgamated products will be featured, including lead lined and antimonial lead products for the handling of corrosive liquids. Fittings and valves will be included in the range of lead, tin lined brass and copper as well as iron specialties.

There also will be displays of metal working and woodworking equipment, metals and alloys, boiler and machine appliances, and a wide range of accessories, such as boiler cleaning compounds, water softening agents, electrical controls, refractories, lubricants, etc.

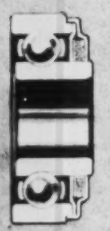
As in previous years, the National Power Show is being held during the same week as the A.S.M.E. Annual Meeting; and a special invitation is extended to all A.S.M.E. members to attend. Tickets of admission can be had without charge at Society Headquarters; and an A.S.M.E. emblem seldom fails to secure for its wearer even more than the usual degree of courteous attention accorded to visitors at booths. In many cases the managers of the booths are A.S.M.E. members themselves; and are glad, accordingly, to welcome a visitor with whom they have a common interest.

See Page 11 for List of Exhibitors

See Page 13 for Floor Diagrams

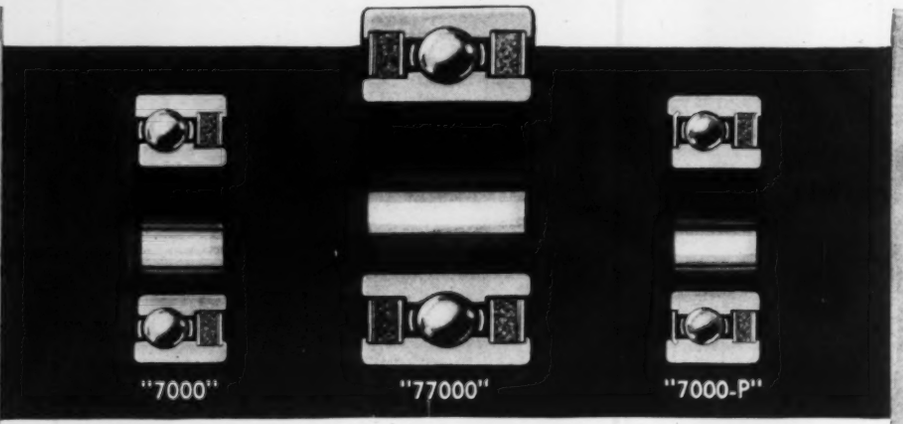
Type P—Closed type ball bearing with one grease - retaining plate.

Type PP—closed type ball bearing with two grease - retaining plates.



Type GS—"Greaseal" felt - protected, grease - packed ball bearing.

Type EGS—Adjustable, felt - protected, grease - packed ball bearing.



SELF-SEALED

Out of their experience of more than 23 years, NORMA-HOFFMANN engineers — pioneers in the design of enclosed and self-protected bearings —have developed and patented a range of types which meets practically every bearing condition and which affords the mechanical world

The Most Complete Line of SELF-PROTECTED BEARINGS in America

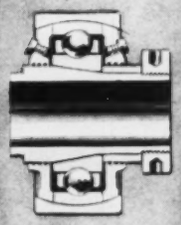
The "GREASEAL" Series of Felt-Protected Ball Bearings—in the three types illustrated above—is marked by the following outstanding features which make for better performance and more lasting satisfaction:- thick, closely-fitting felts between removable plates forming an effective labyrinth against the recessed inner ring - - - FELT SEAL REMOVABLE in its entirety for inspection, cleaning or renewal of grease - - - wide, solid inner and outer rings, with maximum contact on shaft and housing, make inserts in housing unnecessary and militate against slippage, looseness, and escape of lubricant past outer ring - - - felt seal within confines of both rings and not exposed to injury - - - constructional characteristics assuring dimensional exactness and quiet running - - - grease capacity ample for long periods of service. . . . . Eight other types of Self-Protected PRECISION Bearings are here pictured and indexed. Write for the complete Catalog. Let our engineers aid vou in selection and application.

We shall be glad to welcome you at Booths 277 and 278 at the National Power Show

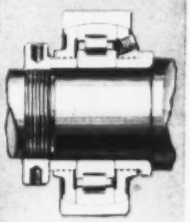
NORMA-HOFFMANN BEARINGS CORPN.
STAMFORD, CONN., U. S. A.

"NORMA-HOFFMANN"
PRECISION BEARINGS

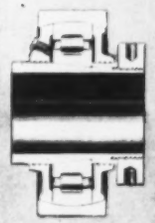
BALL, ROLLER AND THRUST



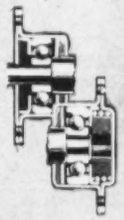
Type LTW—Self - aligning ball bearing with swiveling grease - retaining side plates and adapter sleeve.



Type RLSW—Self - aligning roller bearing with swiveling grease - retaining side plates.



Type RLTW—Self - aligning roller bearing with swiveling grease - retaining side plates and adapter sleeve.



CUP MOUNTING—Designed to use with small open type ball bearings in high-speed devices; furnished as complete units.

Eleventh National Exposition of Power and Mechanical Engineering

LIST *of* EXHIBITORS

Main Floor: Booths 1 to 95 Second Floor: Booths 200 to 348 *See Floor Diagrams on Page 13*

(Corrected to November 22nd, 1934 from list supplied by International Exposition Co.)

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Bradley Washfountain Co.	232
Breuer Electric Mfg. Co.	210C
Bristol Company	12
Brooklyn Borough Gas Co.	7
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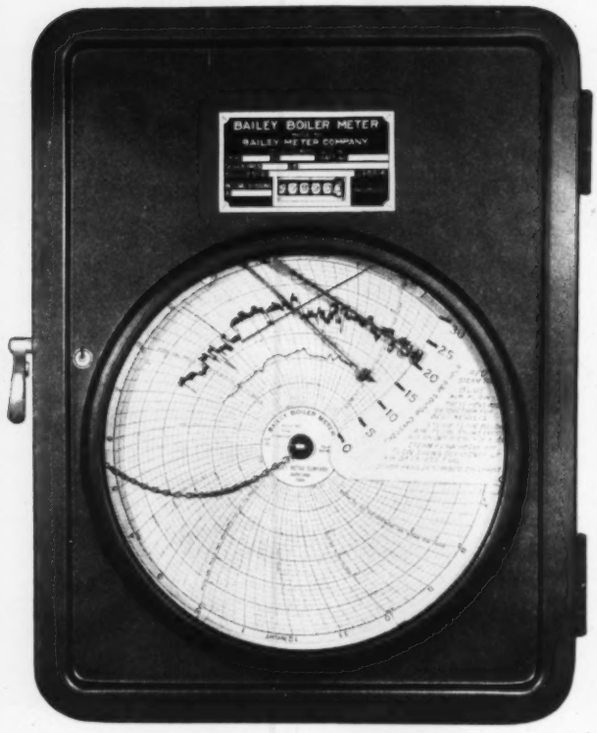
Firms Listed in Bold Face are Advertisers in this Section—See Page 18 for Description of their Exhibits.

Announcing

a New Bailey Boiler Meter for

INDUSTRIAL SERVICE



See this new Boiler Meter at the New York Power Show December 3 to 8, 1934

A NEW BAILEY BOILER METER, simplified in design, sturdy in construction and foolproof in operation, is now available for industrial power plant service. It incorporates a direct reading escapement type integrator, an accurate, sensitive Air Flow Mechanism, a neat appearing dust proof pressed steel casing and a simplified, powerful Steam Flow mechanism with interchangeable head chambers.

This new meter greatly simplifies central station economy methods and places them within easy reach of the small industrial boiler plant. It provides an easily understood, sure fire method of reducing power costs.

Every engineer and executive responsible for steam power costs should investigate this meter. Write for your free copy of Bulletin No. 45.

BAILEY METERS

BOILER METERS
COMBUSTION CONTROL
MULTI-POINTER GAGES
FEED WATER CONTROL
SMOKE DENSITY RECORDERS
FLUID METERS
PYROMETERS
RECORDERS

D-30

BAILEY METER COMPANY

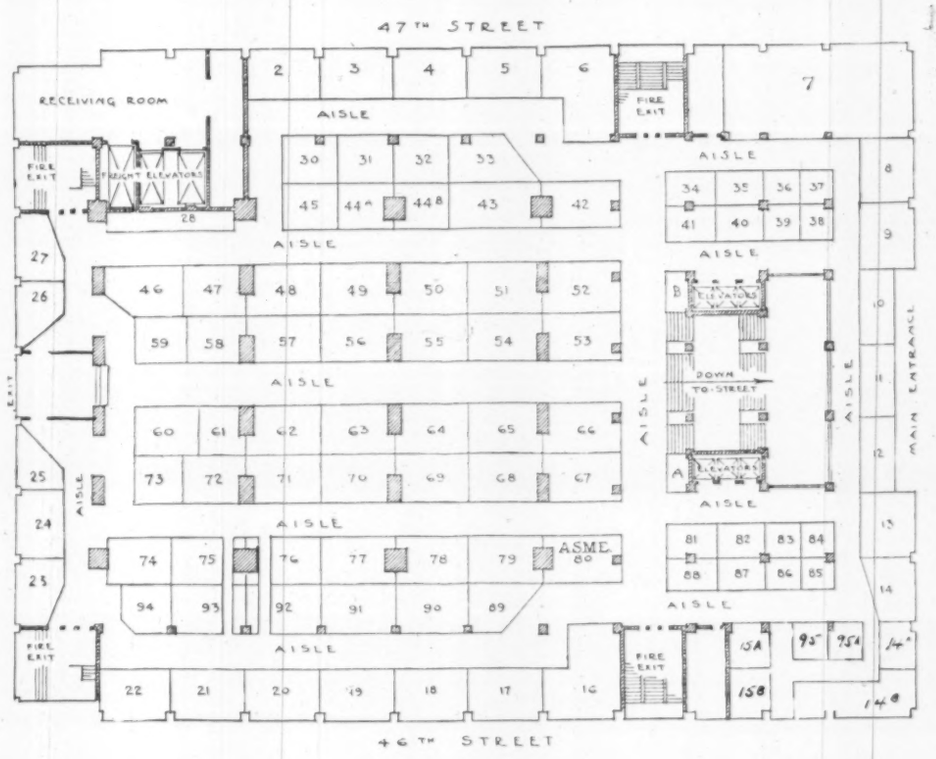
1026 IVANHOE ROAD CLEVELAND, OHIO

Bailey Meter Company Limited, Montreal, Canada

FLOOR DIAGRAMS

Eleventh National Exposition of Power and Mechanical Engineering

December 3rd to 8th, 1934 **Grand Central Palace, New York, N. Y.**



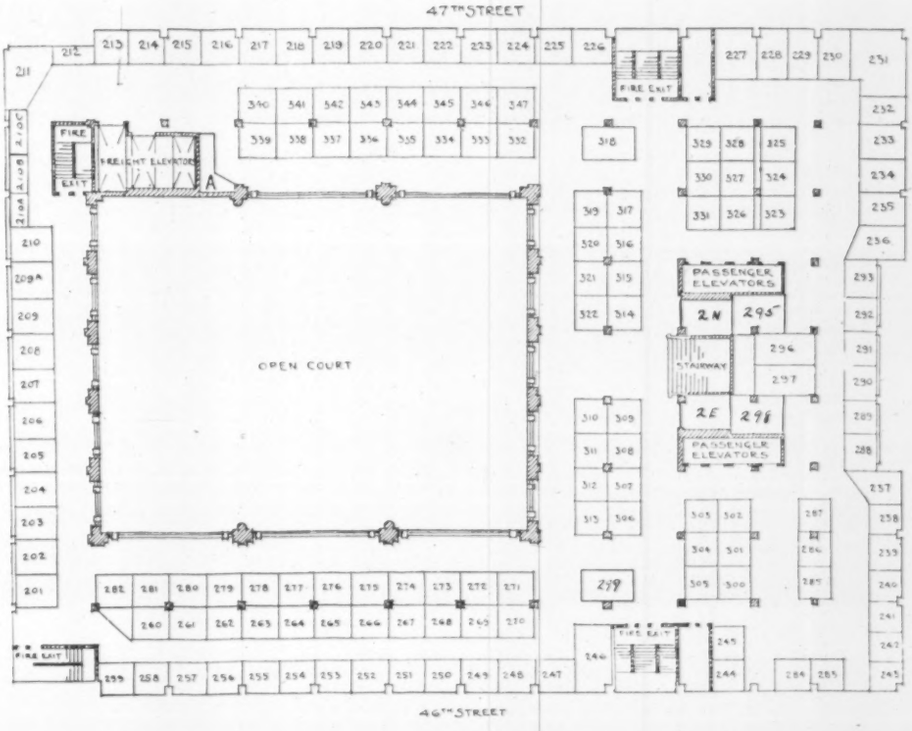
FIRST FLOOR

BOOTHS NOS. 1-95

See page 9 for Story of the Show

SECOND FLOOR

BOOTHS NOS. 200-348



See page 11 for List of Exhibitors

TO BE SEEN AT

REPUBLIC INSTRUMENTS

REPUBLIC FLOW METERS CO. and

TWO LEADERS JOIN FORCES TO RENDER A GREATER SERVICE

Announce New Line of Products

Smoot Engineering Corporation, one of the leading designers and builders of control equipment, has joined forces with the Republic Flow Meters Company, pioneers in the industrial instrument field. The plant of the Republic Flow Meters Company in Chicago has been enlarged by the addition of a third unit to accommodate the Smoot Engineering Corporation whose entire plant, engineering staff and general offices have been moved to Chicago.

This alliance of engineering and manufacturing resources brings to industry, an organization capable of rendering a greater and more complete service in the field of measurement and control. This service is now available through a nation-wide organization of sales and service engineers.

During the past two years, to insure sound, progressive engineering, Republic has enlarged its research facilities, and brought together an even larger staff of research and design engineers. As a result, Republic and Smoot are displaying in Booth No. 6 at the National Exposition of Power and Mechanical Engineering, a complete line of new and redesigned instruments and controls.

Visit Booth No. 6

A NEW REGULATOR FOR INDUSTRIAL PLANTS

A new Smoot regulator known as "Series 50" has been designed primarily for the control of industrial boilers. It embodies all the qualities of sensitivity, power, speed and stability which have earned such an enviable reputation for Smoot regulators among central station operators. This new "Series 50" Smoot regulator brings central station efficiency to the small industrial power plant. It will control furnace draft—boiler air—oil flow—stoker speed or fuel feeder speed.

This new regulator uses either water or oil pressure as a source of operating power. It is equipped with a built-in relay cylinder which will produce ample power to operate dampers or other control devices on industrial boilers. The power requirement does not affect the sensitivity, speed or stability of this regulator.

New Design Features "Cartridge Sealed Elements"

The advance line of Republic electrically operated flow meters while retaining the same basic principle of operation include many engineering features new in the field of instrument design. Each actuating element has been built into a metal cartridge, protecting it against dirt, moisture and abuse. Each "cartridge sealed element" is separate and distinct from every other unit, is interchangeable and can be easily and quickly removed from the instrument panel without disturbing or exposing any other mechanism The indicator scale and recorder chart have uniform graduations and are direct reading. The integrator is a separate instrument of the Watthour meter type. Its operation is continuous, not intermittent, and will therefore follow any variation in flow.

Unit Assembly Features Smoot Master Control

Re-designed to permit unit assembly, the Smoot Master Control is now available in any number or combination of control units desired. This new type of assembly permits the selection of those units necessary for the control of any particular installation whether it be the control of a single 250 H. P. boiler or a battery of central station units.

Visit Booth No. 6

REMOTE TYPE LEVEL AND PRESSURE GAUGE

The new Republic liquid level and pressure gauge will measure static pressures — the pressure head or height of liquids in pipes, tanks, reservoirs or streams. The reading instruments, indicator and/or recorder, are electrically operated and may be located any distance from the point of measurement. This new gauge can also be easily adapted to a signal system or the automatic control of pumps or other equipment.

Visit Booth No. 6

Recording Thermometer With Cartridge Sealed Helix

The helical element of the Republic recording thermometer is built into a cartridge sealed element which is mounted directly to the back of the panel. This eliminates all danger of damaging or changing the calibration due to handling. The bulb, capillary tubing and cartridge sealed helix are welded together forming a sealed thermol system. This entire unit can be easily removed from the panel eliminating the necessity of returning the entire instrument to the factory when repairs or recalibration is necessary.

THE POWER SHOW

SMOOT CONTROL

SMOOT ENGINEERING CORPORATION

A NEW MULTIPLE INDICATOR

The new Republic Multi-point indicator with wide horizontal scales represents the latest development in indicating instruments. It will indicate simultaneously, on separate scales, from two to sixteen units of flow, temperature pressure, percent CO_2, etc., in any combination desired.

Visit Booth No. 6

An Improved Strip-Chart Multiple Recorder

Several important improvements have been incorporated in the Republic strip-chart multiple recorder. This instrument will produce six pen line records simultaneously on one wide strip-chart which is divided into three zones. These records may be any combination of flow, temperature, percent CO_2, etc. The individual "cartridge sealed recording elements" are identical with those used in the individual recorders. Separate indicating scales are mounted above each pen indicating at all times the exact flow, pressure, etc.

Multi-Point Draft and Pressure Indicators

Horizontal scales permit "stacking" desired number of units. Draft and pressure elements employ alum-tanned leather diaphragms the center areas of which are held by pairs of aluminum disks, each supported in vertical position by a long two-point pivot bearing through which diaphragm motion is transmitted. Thus, diaphragms do not support any parts of mechanisms, thus sensitivity is extremely high. Diaphragms being "slack," pressure-measurement function is performed entirely by calibrated phosphor-bronze loading springs. These are of simple flat form, and heat-treated to assure permanence of calibration. Any element can be removed by loosening one screw and one nut, without interfering with adjacent elements. Cases have side plates easily removable for inspecting or interchanging elements, are dust-proof, and are white-enameled inside to aid illumination of translucent scales.

Visit Booth No. 6

SMOOT TURBINE TYPE REGULATING VALVE

This valve is designed for the regulation and control of high pressure, superheated steam or boiler feed water. It is a gradual opening, high lift, balanced valve. The throat of the valve is shaped like a turbine steam nozzle but with a regulated area. The direction of the stream lines in the flow is always parallel to the surface of the valve head and seats, thus permitting a smooth passage with practically no erosive action. The valve stem and discs are a one-piece forging. The valve may be either lever or hydraulic operated. Hydraulic operation is obtained by means of a double acting power cylinder which is mounted on the valve bonnet. These valves are available in any size ranging from ½ inch to 20 inches for pressure from 125 lbs. to 1,500 lbs.

Visit Booth No. 6

A NEW MECHANICAL FLOW METER

Republic announces a new mechanical flow meter which is an extremely simple and accurate flow metering device, designed primarily for those installations where remote registration is not required. The entire instrument is mounted on a 16x24 inch steel panel. The recorder, which has a 12-inch evenly divided chart, the indicator, and the synchronous motor driven integrator are flush mounted on the front of the panel. The meter body, which is of the mercury float type, is mounted on the back of the panel forming a compact, sturdy unit. You will immediately recognize the merits of this new instrument which is outstanding because of its utter simplicity.

Visit Booth No. 6!! at the Power Show

Inspect the complete line of new and redesigned meters and controls offered by

Republic Flow Meters Co.
Smoot Engineering Corporation

General Offices: 2240 Diversey Pkway., Chicago, Ill.

The MOTOR with 1000 Speeds

Equipped with SKF Plus-Performance Bearings

U.S. VARIDRIVE

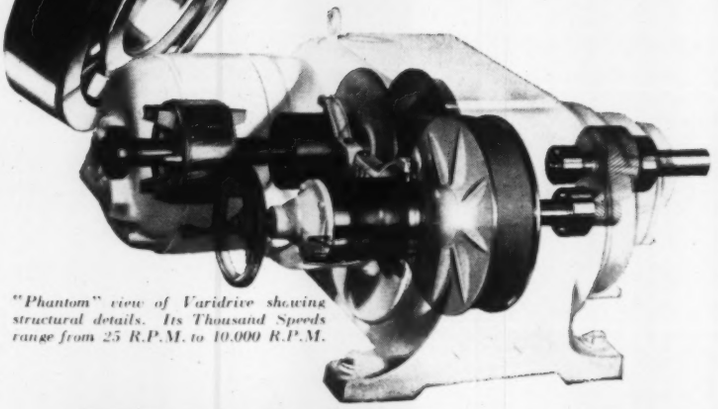
U. S. Varidrive Motor built by U. S. Electrical Mfg. Co., Los Angeles, Calif., equipped throughout with SKF Bearings.

3317

ANOTHER make of bearing, produced without the repeated inspections, the constant testing to which every SKF Bearing is subjected, *might* have given satisfactory service in *some* Varidrive installations. Another make of bearing *might* have stood up for a while. But no manufacturer today, or at any other time, can afford to take a chance on his product falling down, simply because the bearing he selects can't stand up.

And so the choice of the U.S. Electrical Mfg. Co., manufacturers of the U. S. Varidrive, the Motor with 1000 Speeds, was SKF Plus-Performance Bearings.

The simple statement, "SKF-equipped", on a product or in a catalog, is a very generally accepted warranty of the quality of the product itself... SKF INDUSTRIES, Inc., Front Street and Erie Avenue, Philadelphia, Pa.



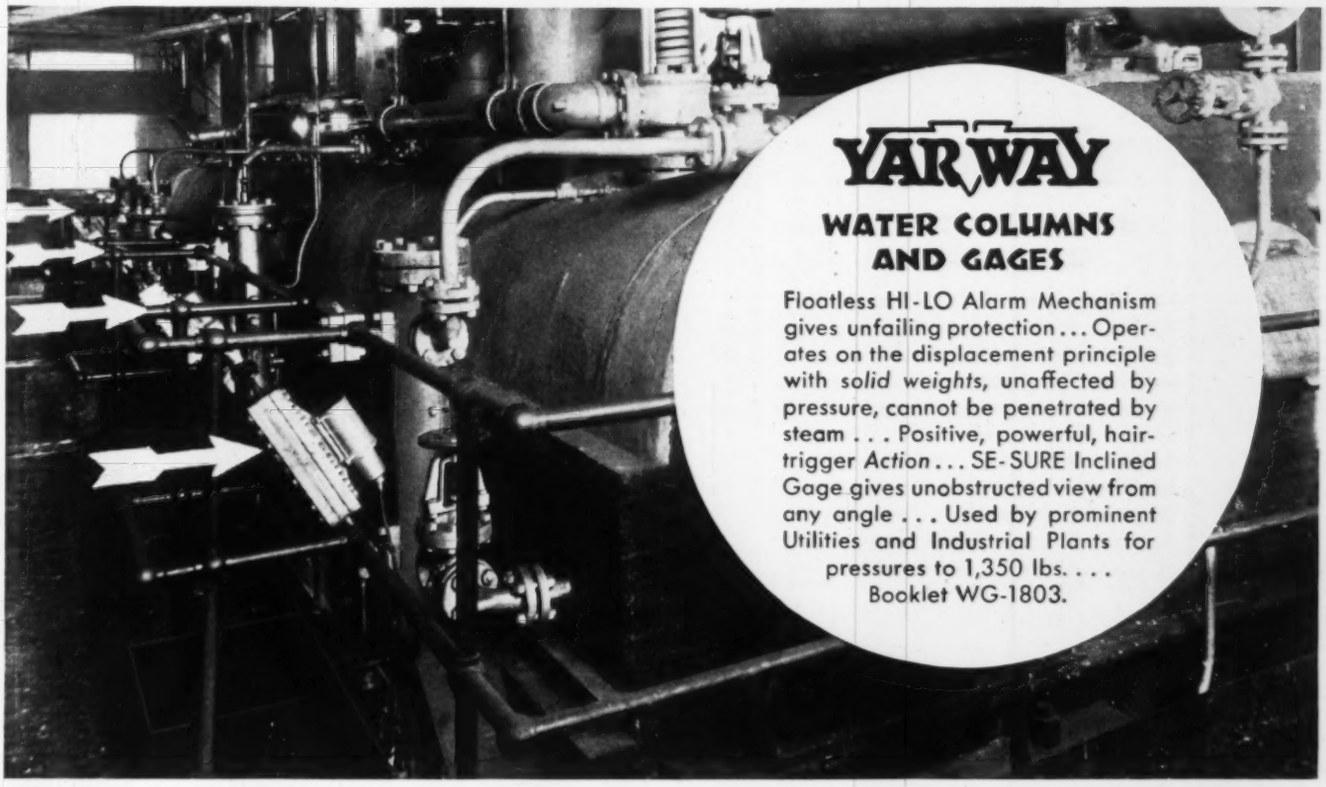
"Phantom" view of Varidrive showing structural details. Its Thousand Speeds range from 25 R.P.M. to 10,000 R.P.M.

SKF

BALL AND ROLLER BEARINGS

"YARWAY EQUIPPED"

A mark of good Engineering

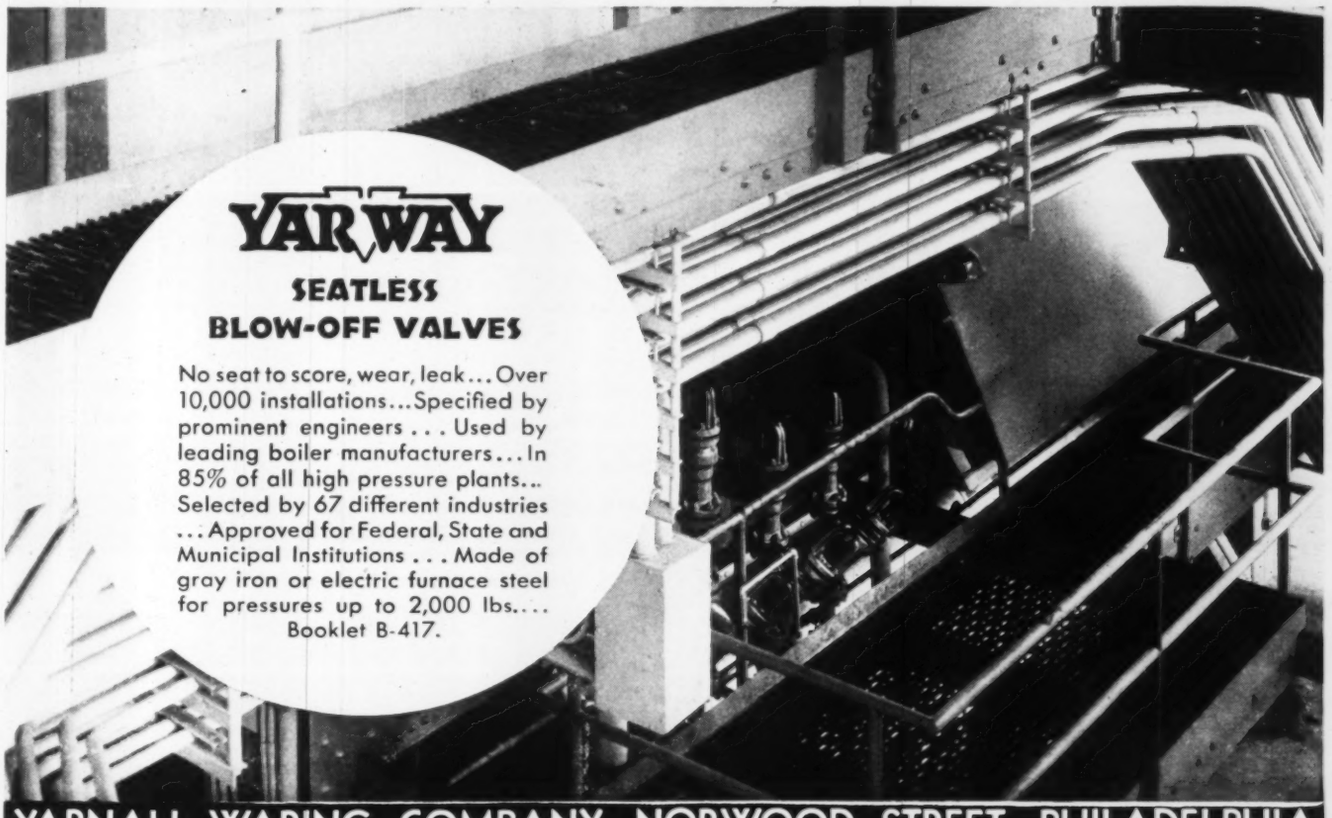


YARWAY

WATER COLUMNS AND GAGES

Floatless HI-LO Alarm Mechanism gives unfailing protection... Operates on the displacement principle with *solid weights*, unaffected by pressure, cannot be penetrated by steam . . . Positive, powerful, hair-trigger *Action*... SE-SURE Inclined Gage gives unobstructed view from any angle . . . Used by prominent Utilities and Industrial Plants for pressures to 1,350 lbs. . . . Booklet WG-1803.

See the YARWAY Exhibit · Booth 66 · National Power Exposition, New York, Dec. 3 to 8.



YARWAY

SEATLESS BLOW-OFF VALVES

No seat to score, wear, leak... Over 10,000 installations... Specified by prominent engineers . . . Used by leading boiler manufacturers... In 85% of all high pressure plants... Selected by 67 different industries ... Approved for Federal, State and Municipal Institutions . . . Made of gray iron or electric furnace steel for pressures up to 2,000 lbs.... Booklet B-417.

YARNALL-WARING COMPANY, NORWOOD STREET, PHILADELPHIA

Clean, Economical Gas Heaters for the Cold Spots

Nearly every plant has them—two or three spots where the existing heating system does not do a suitable job.

In such situations—a Buffalo Gas Unit Heater works wonders! It supplies CLEAN Heat—no dust or smoke. It is economical, considering the small investment and the fact that it requires no "stand-by" equipment.

And it HEATS—as much or as little as you want! Hundreds of these units, both floor and suspended types are in service in every type of building.—Why not write for Bulletin 2852.

See our Exhibit at NEW YORK POWER SHOW December 3rd to 8th, 1934

We are showing a complete Buffalo Induced Draft Fan of the type which many of the largest power plants use, as well as other fans and a Unit Heater. Be sure to visit us at Booth 49.

Buffalo Forge Company

148 Mortimer Street Buffalo, N. Y.

In Canada:

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo" GAS and STEAM Unit Heaters

EXHIBITS of ADVERTISERS in this section

See Page 11 for List of Exhibitors and Page 13 for Floor Diagrams

Bailey Meter Co. ..... Page 12

Will show for the first time, a new and simplified Bailey Boiler Meter for industrial service. This new boiler meter, which greatly simplifies central station economy methods and places them within easy reach of small industrial boiler plants, provides an easily understood, sure fire method of reducing steam power cost. A Bailey Meter air-operated combustion control system will be in operation demonstrating the method by which the new Steam Flow-Air Flow Bailey Boiler Meter automatically maintains highest combustion efficiency consistent with economical operation. This control system will also demonstrate the method by which Bailey Meter Control maintains steam pressure and furnace draft in addition to combustion efficiency. In addition to the sections and operating units of the automatic control system, eight colored and illuminated diagrammatic drawings, showing the application of Bailey Meter Combustion Control and Bailey Meters to various types and sizes of industrial, municipal, and central station boiler plants, will be on exhibit. The Bailey Fluid Meter for the measurement of steam, gases, and liquids will be displayed as well as the Bailey Feed Water Regulator. H. M. Hammond, Manager of Sales and Engineering, will be in charge.

Boston Gear Works (Inc.) ..... Page 19

Will exhibit representative types of Boston Gear stock products of every description, consisting of Gears, Speed Reducers, Reeves Variable Speed Transmission; Renold-Boston and Duckworth-Boston Inverted Tooth and Roller Chain Drives, Doehler-Boston Die-Cast Stock Gears, Curtis Universal Joints, "Nice" Ball Bearings, Light transmission parts, etc. Exhibit will include a movable display of a Boston Motorized Speed Reducer.

Buffalo Forge Co. ..... Page 18

Will exhibit a complete No. 5½ SSLD Induced Draft Fan with water cooled bearings of the type generally used in modernization of power plants. Other equipment shown will include a Highboy Unit Heater (operating), A Breezofin Unit Heater (operating), a No. 3 CL Fan with silent floating base and V Belt Drive (operating), and a rubber covered Exhaust Fan. Of interest to engineers will be an exhibit of forced and induced draft fan blades showing the curvature used in each type. Publishers of the Handbook "Fan Engineering." J. E. Gill of the Buffalo Engineering Department will be in charge.

Foster Engineering Co. ..... Page 19

Featuring a display made up of a panel background arched, in two colors of velour, with a window cut out in the middle near the top. Back of this panel cut out models rotate so that they pass the window. Flood lights bring these models out in bold relief, so that they may be seen from the exhibition floor. Will also have a number of cut out models stationary on tables. Bulletins, circulars and folders will be available.

Garlock Packing Co. ..... Page 20

Will feature the Garlock KLOZURE. This is a new oil seal development on which Garlock released the first publication advertisements this month. The Exhibit will center around a working model on which Garlock KLOZURES are used.

General Insulating & Manufacturing Co. ..... Page 19

Featuring their complete line of Gimco Rock Wool Thermal and Sound Insulation. A staff of engineers will be present at all times to discuss insulation problems and answer questions pertinent to industrial and house insulation.

Norma-Hoffmann Bearings Corp'n ..... Page 10

Displaying a complete range of types and sizes of their ball, roller, and thrust bearings, as well as their ball and roller bearing equipped pillow blocks and mountings. Will also feature this year their completely enclosed felt protected ball bearings, as well as bearings of the snap ring type, both of which have been constructed with the idea of reducing bearing mounting costs. The following representatives will be in attendance at their booth: O. P. Wilson, H. J. Ritter, G. R. Bott, D. E. Batesole, F. W. Mesinger, T. E. Rounds, R. Gannett, R. V. Donnelly, G. Tompkins, T. M. Kaino, and W. A. P. Nones.

Republic Flow Meters Co. ..... Pages 14, 15

Showing an unusually interesting group of their most recent developments in combustion controls and power plant and industrial instruments, among which will be the following: A Smoot 8-tube master control panel is being displayed to duplicate the similar installations in various large Central Stations. On this panel assembly are arranged the corresponding Republic Instruments, including the two multiple pen continuous record strip chart recorders on which all of the combustion and control records are prepared. Smoot Regulators actually in operation will illustrate their sensitivity. One is a completely new design of Smoot Regulator made to sell for a substantially reduced price, for accurate regulation of small boiler plants. Also Republic's latest development; a low cost mechanical meter including many of the outstanding features of the new style Republic electrically operated meter.

S K F Industries (Inc.) ..... Page 16

Showing a complete line of heavy duty ball and roller bearing pillow blocks, ball and roller bearings, and ball bearing hangers. Headquarters will be at the Hotel Lexington, and those attending will include: R. H. DeMott, General Sales Mgr.; R. C. Byler, Adv. Mgr.; F. E. Ericson, Asst. Sales Mgr.; D. W. McAllen, Supervisor of Distributors; J. D. Williamson, N. Y. Dist. Mgr.; Harrison Wood, C. A. Decker, J. C. Gayler, and W. B. Ashland, N. Y. District Office, and Frank Crow and G. E. Allen from Home Office.

Smoot Engineering Corp'n ..... Pages 14, 15

(See Republic Flow Meters Co.)

Yarnall-Waring Co. ..... Page 17

The new features this year are: (1) Yarway Blow-off Valves adapted for working pressures of 1600 lb. and below, etc. (2) Yarway Floatless Hi-Lo Alarm Steel Water Columns of new compact design. (3) Unique design of Yarway Sesure Inclined Gages as well as Vertical Gages. (4) Yarway Gun-Pakt and Gland-Pakt All Wrought Steel Welded Expansion Joints. (5) Yarway Eye Line Water Level Indicator. A full sized working model of this unit has been provided. (6) Enlarged (4′ × 3′) photographs of actual installations of the above power plant devices will be displayed.

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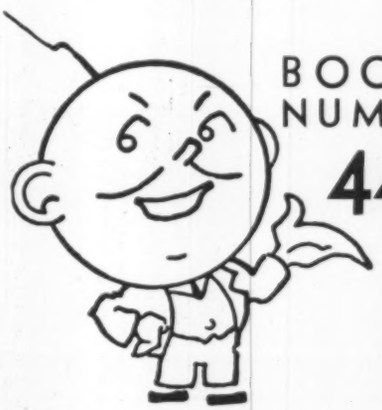

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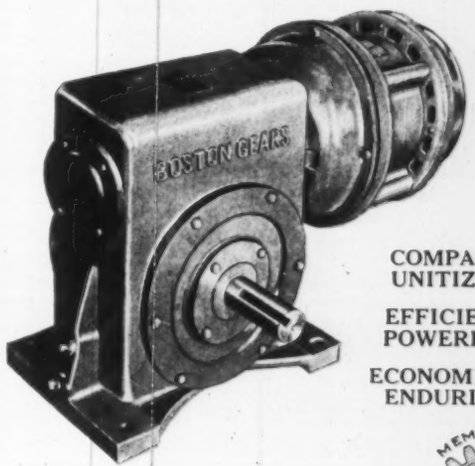

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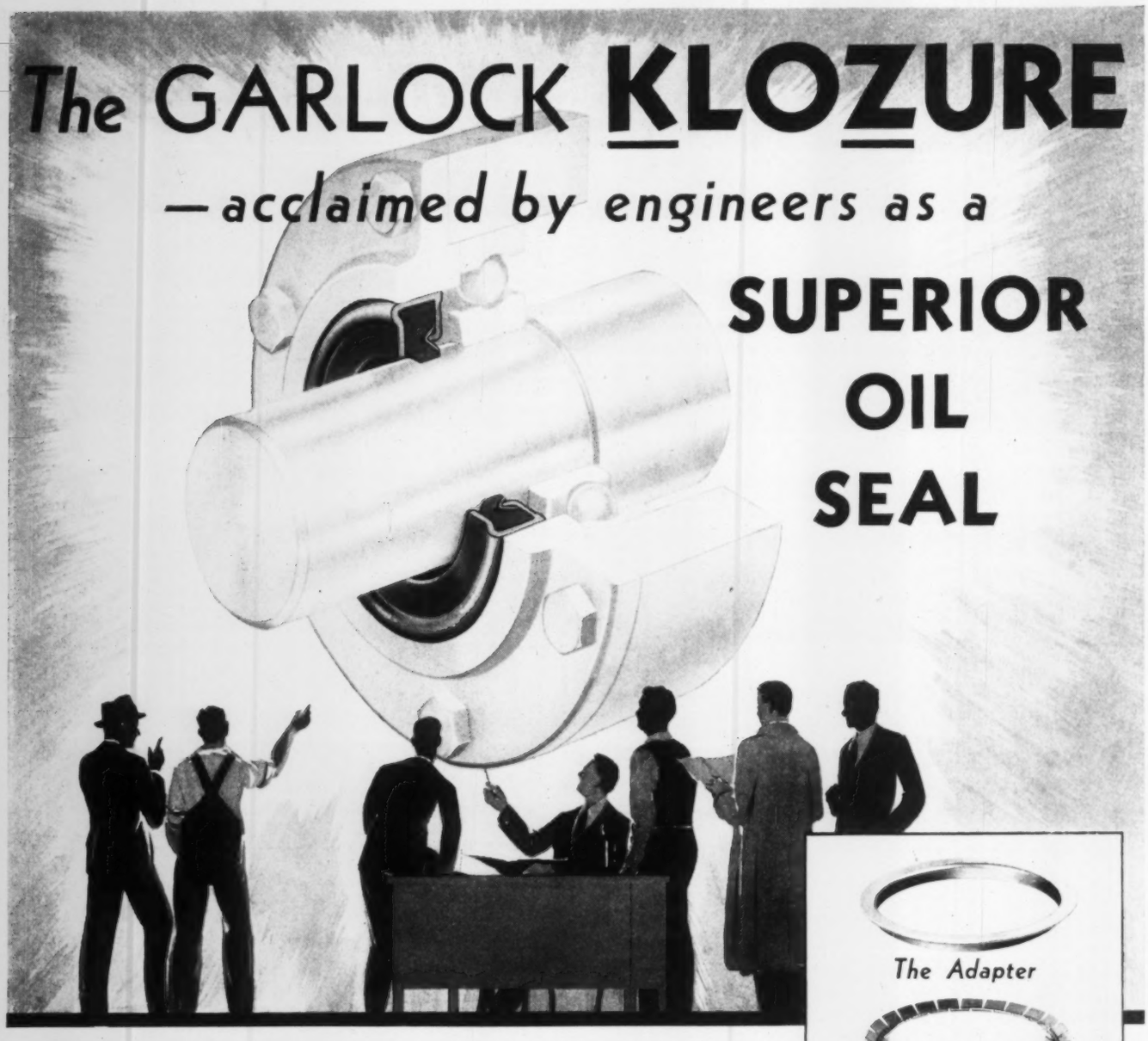

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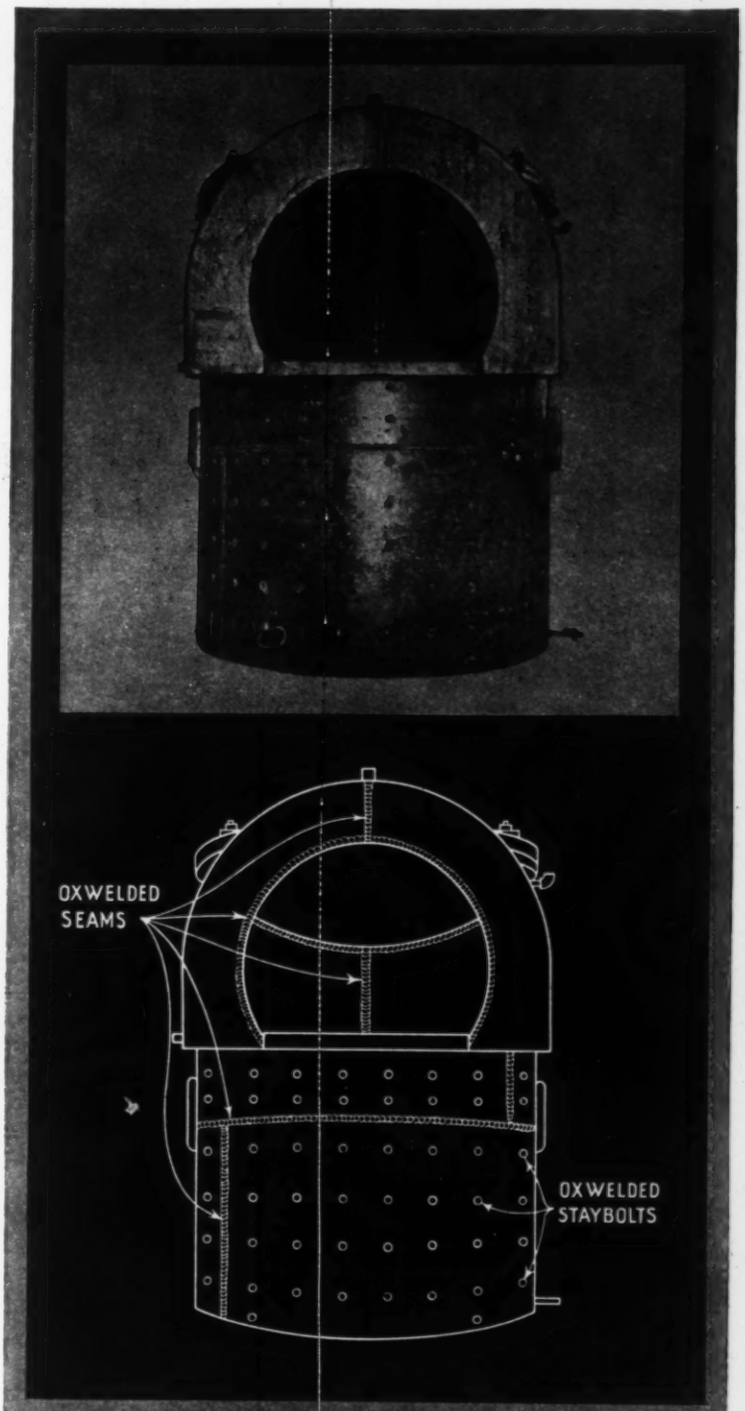

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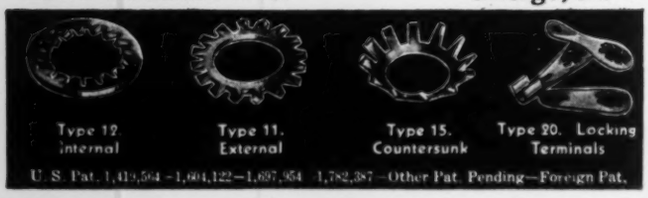
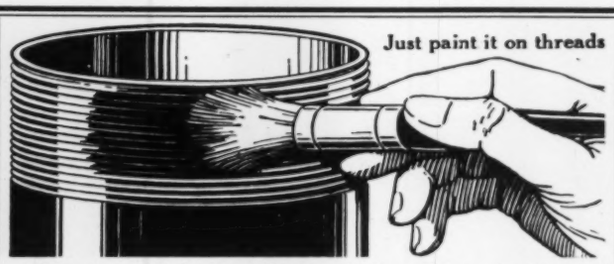


U. S. Pat. 1,419,564—1,604,122—1,697,954—1,782,387—Other Pat. Pending—Foreign Pat.



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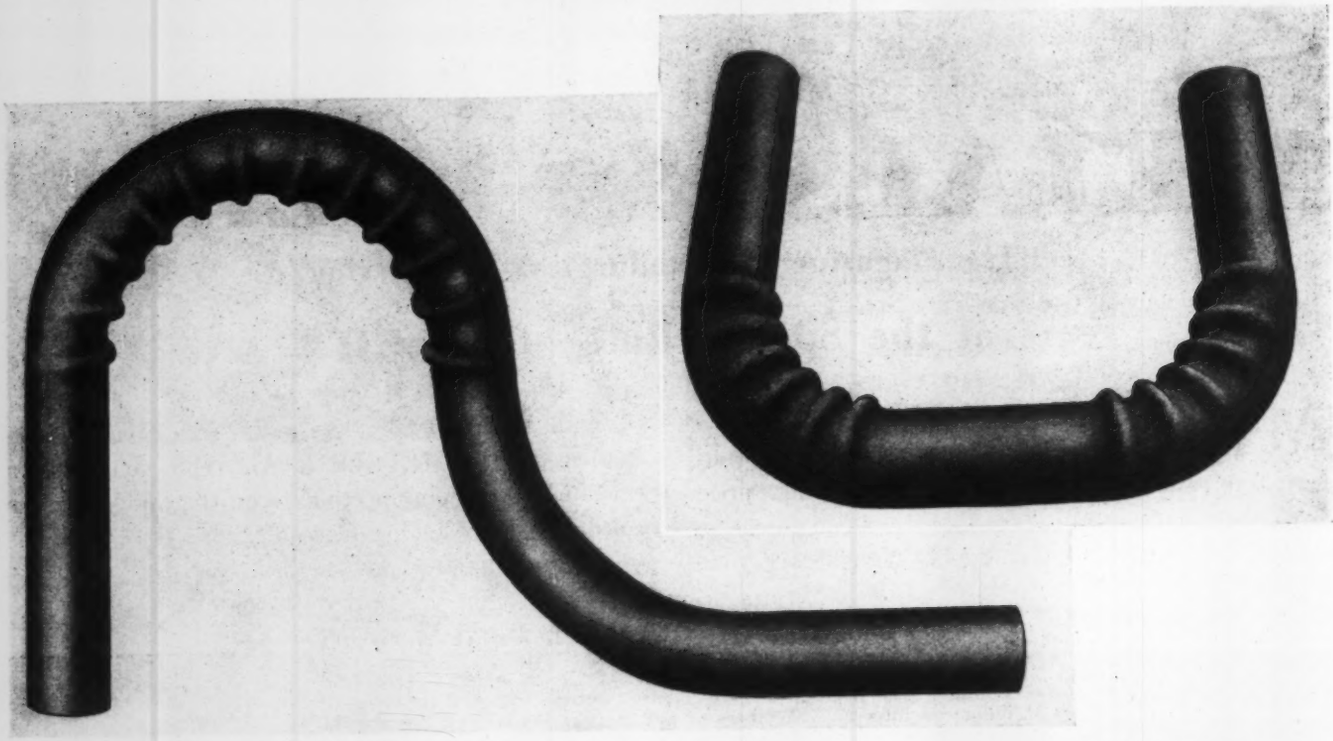

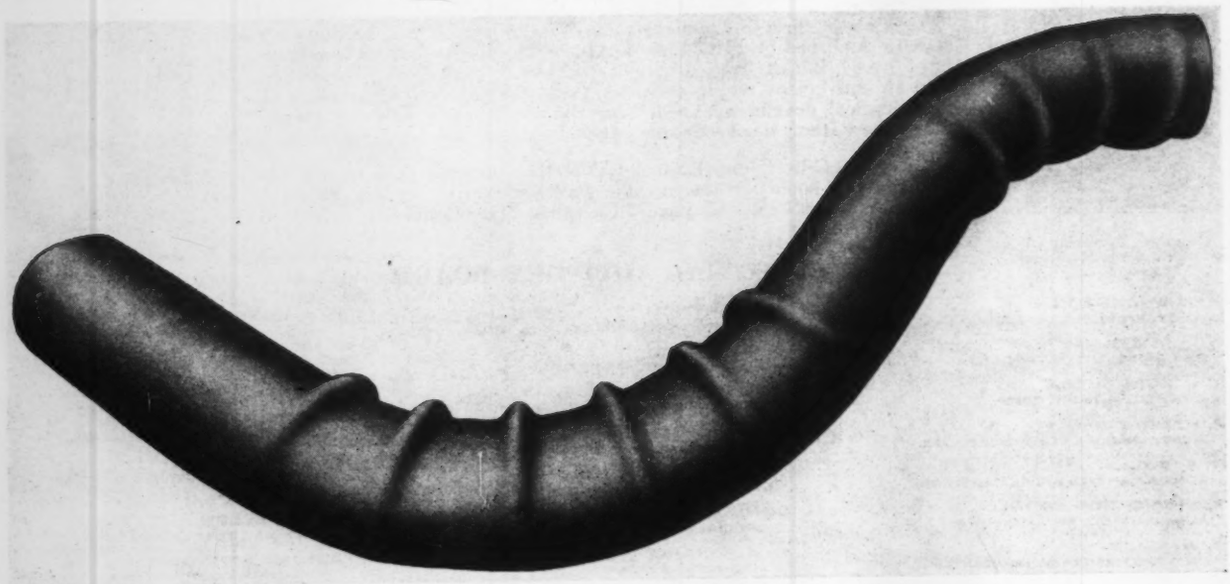

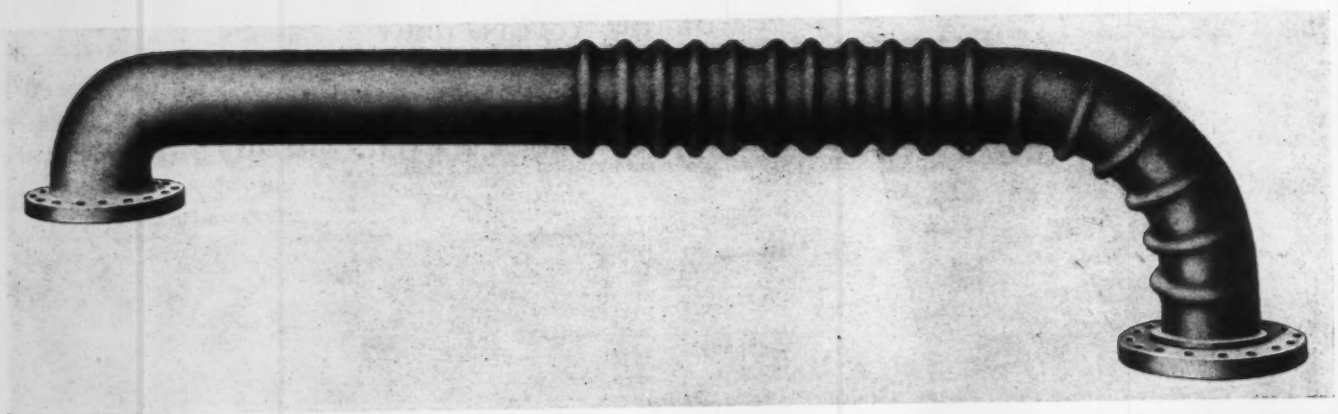

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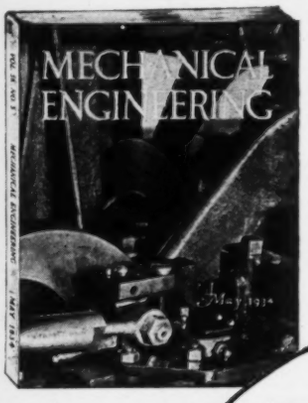

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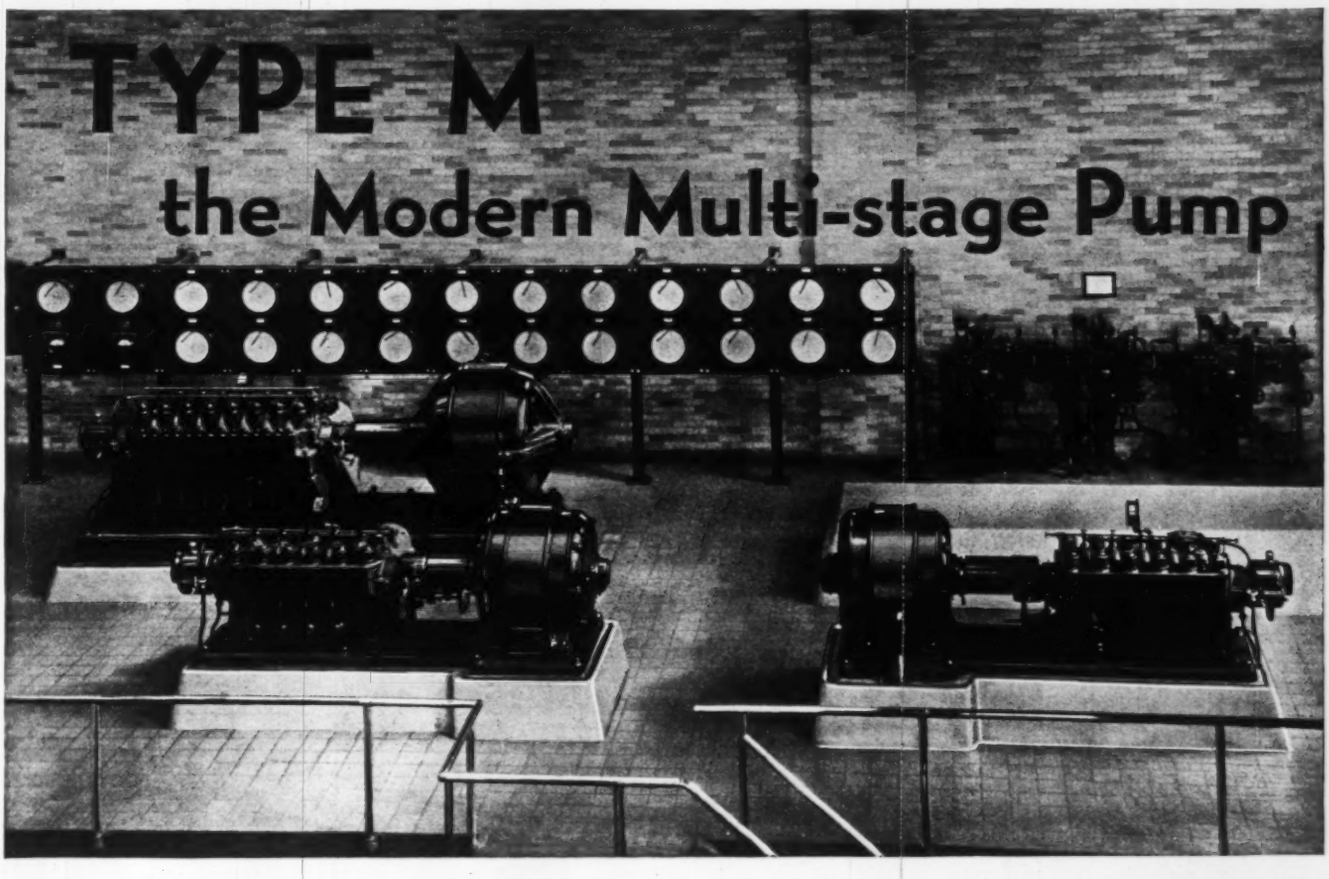

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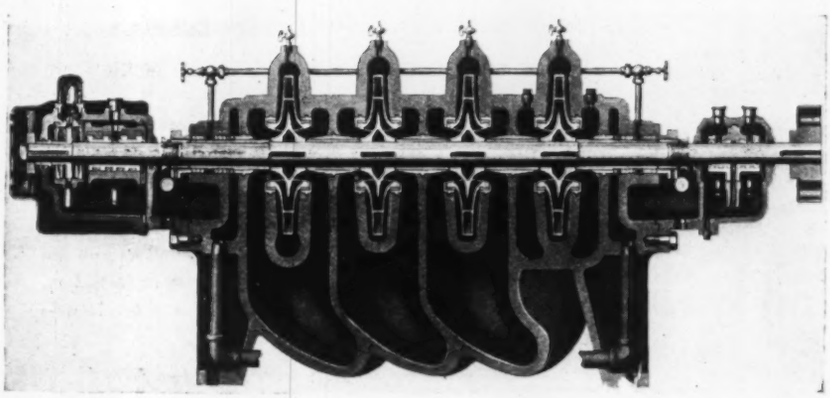

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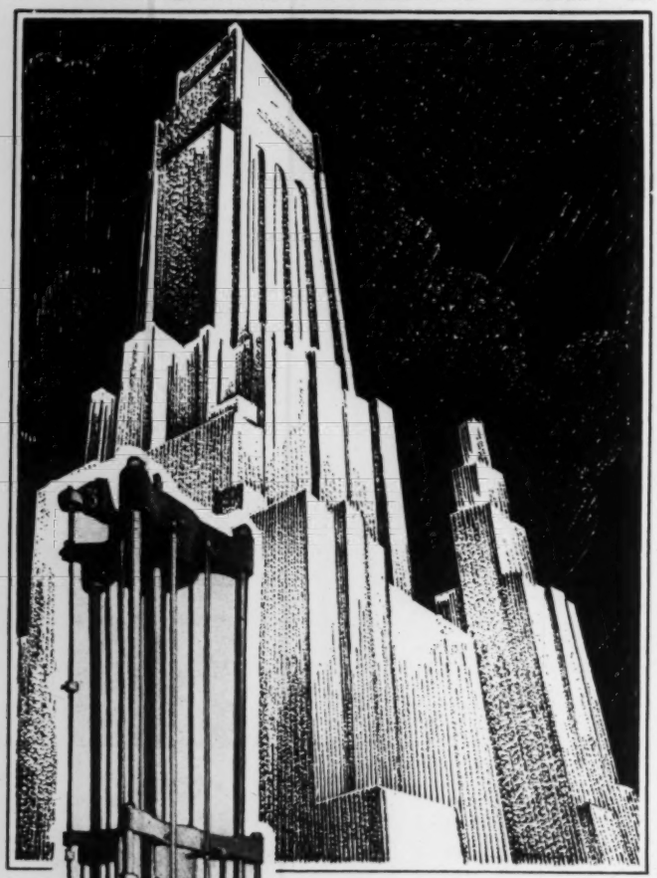

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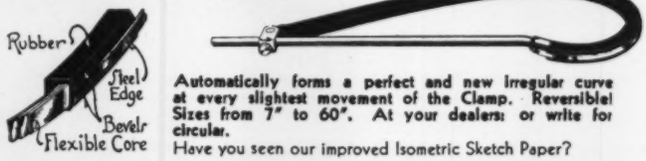

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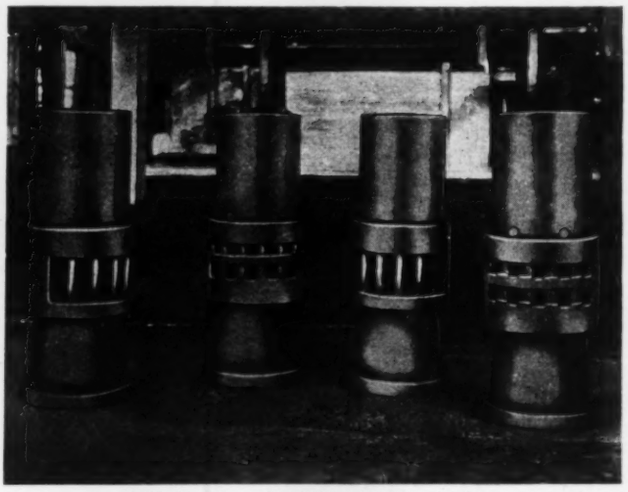

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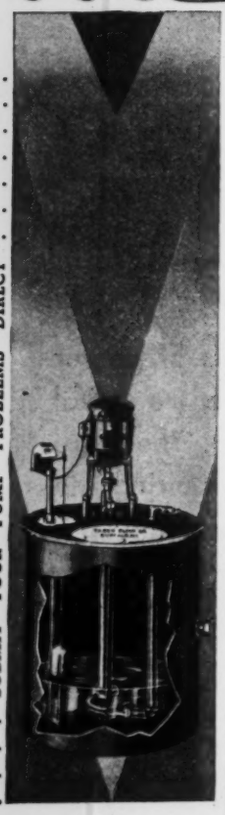

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$2,500 to $25,000

This thoroughly organized advertising service of 25 years' recognized standing and reputation carries on preliminary negotiations for positions of the caliber indicated, through a procedure individualized to each client's personal requirements. Several weeks are required to negotiate and each individual must finance the moderate cost of his own campaign. Retaining fee protected by a refund provision as stipulated in our agreement. Identity is covered and, if employed, present position protected. If you have actually earned over $2,500, send only name and address for details. R. W. Bixby, Inc., 115 Delward Building, Buffalo, N. Y.

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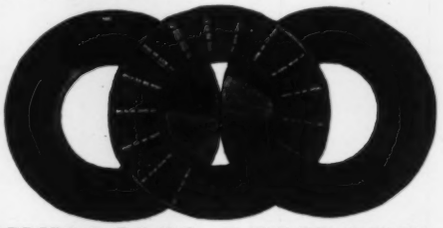

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AMERICANS get more out of the telephone than any other people in the world.

Partly it is because we still have the pioneer qualities. We are restless, inquisitive, ambitious, sociable, ingenious, enterprising. The telephone is adapted to us and we are adapted to the telephone. But another reason why the average American uses the telephone more is that there are more telephones to use—more than thirteen million in the Bell System alone. And the service is better.

There are few persons in this country so isolated that the telephone cannot find them. Because everybody knows this, the telephone is kept busy and everybody gets more out of it. Your telephone grows in value the more you use it—the more you rely on it to help you through the day's activities.

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More than 57,000,000 conversations a day are held over Bell System wires. It takes a telephone system of great size to render quick, reliable service to a great nation.

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Advertising Forms of MECHANICAL ENGINEERING close on the sixth of the month preceding date of issue.

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Eliminate Needless Dangers with a

Squires BOILER FEED WATER CONTROLLER

Undue strains on the boilers can be eliminated by installing this simple and reliable feed water controller. It will shoulder human responsibilities with exacting precision.

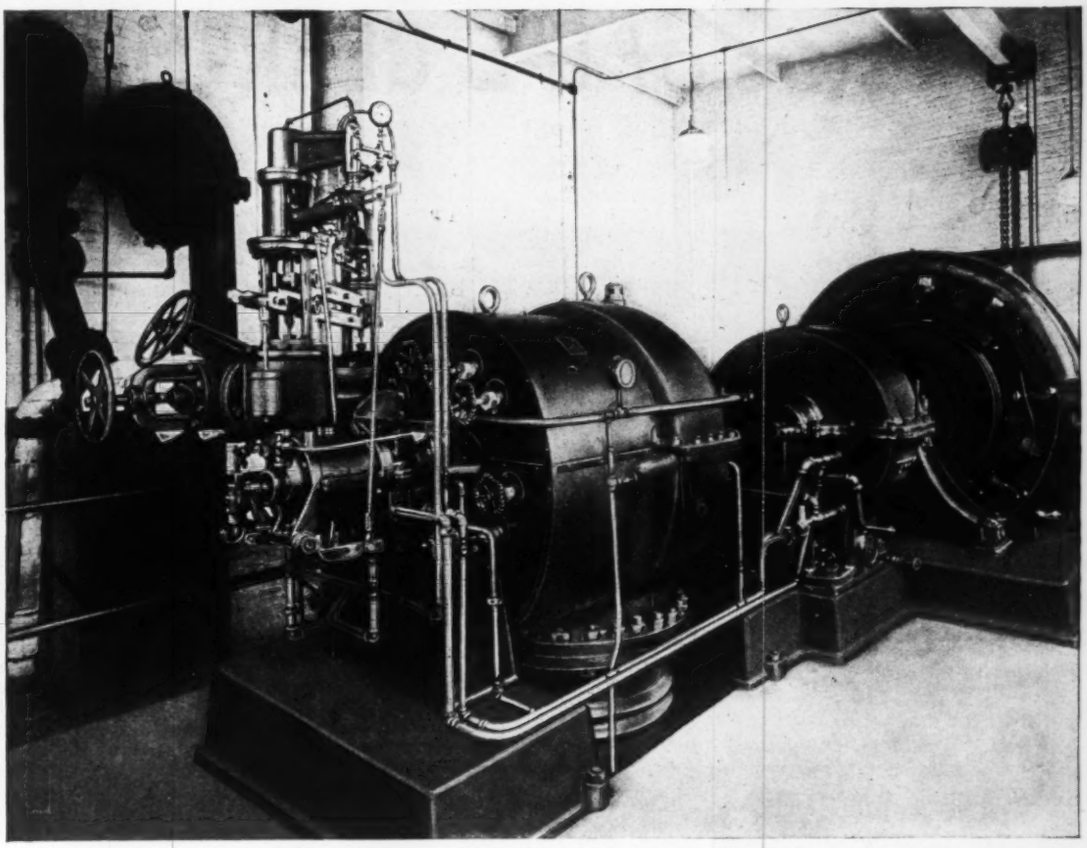
Write for full particulars (H-12)

THE C. E. SQUIRES CO.

E. 40th St. AND KELLEY AVE. CLEVELAND, OHIO

Trade Mark Reg. U. S. Patent Office

TERRY



"OPERATING ECONOMICALLY FOR EIGHT YEARS WITHOUT A MOMENT'S TROUBLE."

Thus writes Mr. Roland H. Guinsburg, Vice Pres. of the I. B. Kleinert Rubber Company of New York, in referring to the 750 KW Terry mixed pressure unit installed by his company in 1926.

He states further, "During the period we have, on several occasions, taken the engine down for examination and in each instance we found the working parts in perfect condition. Our coal bills have been reduced, and our water consumption is much less than formerly, and we are in every respect well satisfied with the unit."

Terry-Generator Units are available in all types and sizes up to 1000 KW. May our engineers consult with you?

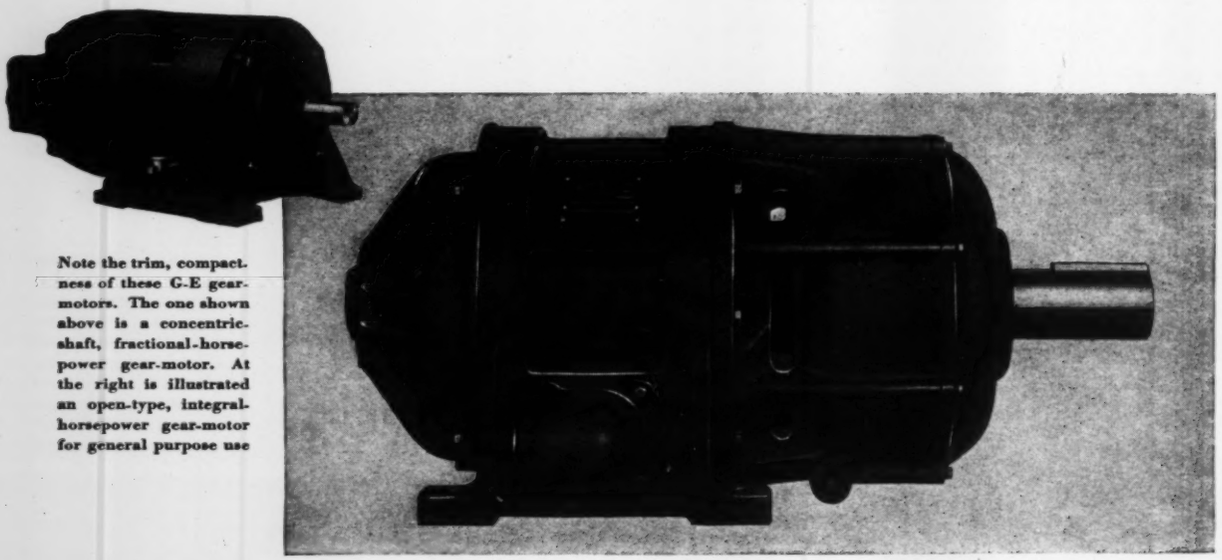
T-1100

The TERRY STEAM TURBINE COMPANY

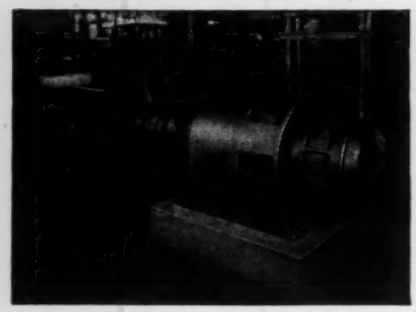
TERRY SQUARE, HARTFORD, CONN.

Steam Turbines - Gears

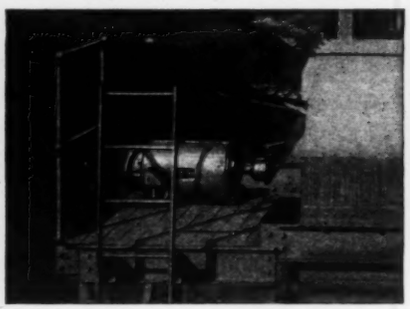
"We have cut costs and saved space" say users of G-E GEAR-MOTORS



Note the trim, compactness of these G-E gear-motors. The one shown above is a concentric-shaft, fractional-horsepower gear-motor. At the right is illustrated an open-type, integral-horsepower gear-motor for general purpose use



The United Wire and Supply Corporation: "G-E gear-motors enabled us to improve our tubes, cut power costs, and reduce our over-all power investment."



The Stephens-Adamson Company: "By means of G-E gear-motors, we were able to reduce the construction costs of the Potomac Electric Company's new coal conveyor for its Buzzard Point Station."

The National Card Mounting Company: "G-E gear-motors added convenience, reduced noise, and saved space in our plant." The gear-motor shown provides and maintains the exact speed required

STATEMENTS like these indicate some of the advantages provided by G-E gear-motors. Wherever you need compact, efficient, low-speed drives, you'll find it profitable to use G-E gear-motors. They're built to "stand the gaff" of the hardest service — built to stay on the job year after year.

G-E gear-motors are available in standard voltages and ratings from 1/6 to 75 hp., from 11 to 600 rpm. They can be supplied in all the electrical and mechanical modifications available in general-purpose motors.

If you wish additional information, address General Electric, Dept. 6C-201, Schenectady, New York.

020-99

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Build high thrust capacity

INTO INDUSTRIAL MACHINERY WITH

M-R-C BALL BEARINGS!

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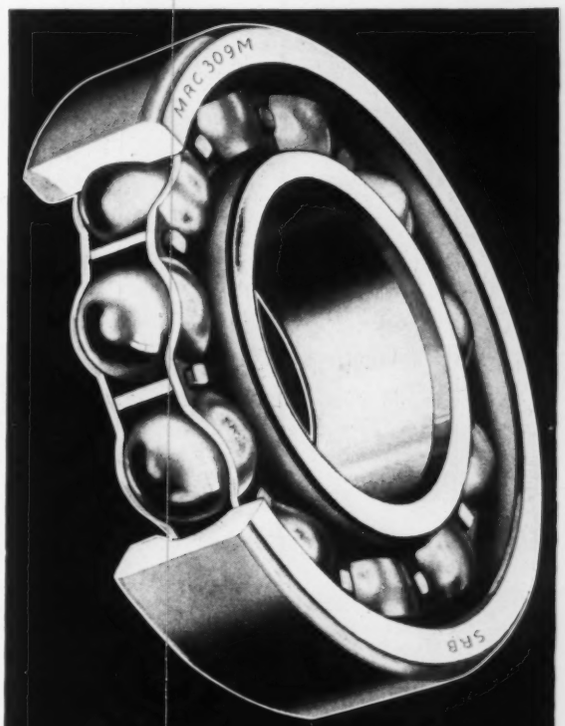
● The M-R-C Type M is the result of continuous research and unceasing effort to produce a single-row ball bearing with highest possible capacity and longest life. It contains the maximum number of largest size balls consistent with a well-balanced design, directly responsible for its enormous capacity. Deep race-grooves provide high side-shoulders against which thrust may be applied from either direction.



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Factories: Jamestown, Plainville, Conn., Chicago

M-R-C MAXIMUM CAPACITY—SRB TYPE M . . . ALSO AVAILABLE IN SNAP-RING AND LUBRI-SEAL CONSTRUCTION.

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On Steel Mill Roll Necks

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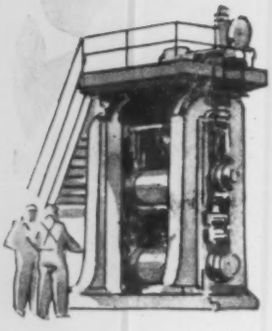

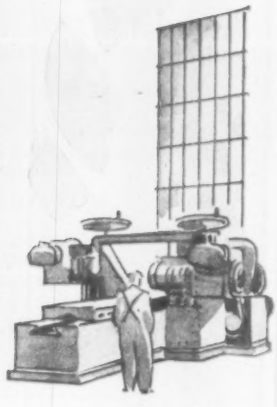

VERSATILITY is a valuable virtue of Timken Tapered Roller Bearings. Where extreme precision is required, as on heavy duty machine spindles; or where sheer brute strength is needed to carry loads measured in millions of pounds, as on steel mill roll necks, Timken Bearings function with the same frictionless smoothness and endurance.

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